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U. S. NAVY AMPHIBIOUS CARGO BEACHING LIGHTER (ACBL) - TRI-MODULE CONCEPT DESIGN AND DEVELOPMENT

PHASE II - FINAL REPORT

An Investigation Conducted by:

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13. ABSTRACT *(Maximum 200 words)*

This report documents a conceptual design effort for the Amphibious Cargo Beaching (ACB) Lighter, a modular barge system that is being developed to replace the Navy Lighter (NL) pontoon causeway system. The ACB Lighter will be rapidly deployed from an auxiliary crane ship and be assembled and operated in sea conditions through sea state three to support Joint Logistics Over the Shore (JLOTS) operations. The system design requirements, operational goals, objectives, and constraining factors were addressed in the Phase I effort (NFESC CR 96.012 (ADA318210)). In addition, conceptual designs of a monolithic module as well as an intermodal module concept, the Tri-Module, were presented and evaluated against manufacturing cost, maintainability, reliability, and interoperability considerations. This Phase II effort focused on development of the Tri-Module concept, addressing the integration of the Navy rigid and flexible connection concepts into the structure, the design of a beach-end ramp, and evaluation of various ramp concepts to interface the ACBL system with the Navy Lighter (NL) and Modular Causeway Section (MCS) systems.

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1 INTRODUCTION

This report, in conjunction with the Vu-graph presentation (Appendix B), presents the results of a design study related to the development of an Amphibious Cargo Beaching Lighter (ACBL). This study was conducted by M. J. Plackett & Associates (MJP&A) from February through May 1996 under Contract Number N47408-95-C-0201 for the Naval Facilities Engineering Service Center (NFESC), Port Hueneme, California. The objectives of this study were to investigate and expand the Tri-Module ACBL concept proposed during the Phase I study (reference 1).

Specific issues addressed in this study include the integration of the Navy rigid and flexible connection concepts into the Tri-Module structure, the design of a beach-end ramp and evaluation of various ramp concepts to interface the ACBL system with the Navy Lighter (NL) and Modular Causeway Section (MCS) systems. To support this study, a 1/35th scale model was designed and fabricated to illustrate the major features of the Tri-Module concept. This model includes raked-end, center and beach-end Tri-Module units.

2 TRI-MODULE ACBL

The Tri-Module concept evolved during the Phase I study because of the difficulties encountered trying to meet the 30 long ton weight limitation of a 40-ft by 24-ft by 8-ft high monolithic ACBL unit and the problems associated with handling and transporting such large structures. The Tri-Module concept (Figure 2-1) solves the overland transport problem by separating the ACBL unit into three separate ISO-compatible modular units. Because the ISO-compatible modules can be transported conventionally, fabrication does not have to be limited to, typically more expensive, waterfront manufacturers.

After the modules have been fabricated, they are transported to a dockside facility where they are connected together to form a 40-ft long by 24-ft wide ACBL Tri-Module. Because the spaces next to the stacking corners must be clear to allow loading in adjacent container cells aboard the ship, the Tri-Module concept makes use of removable posts that support the ISO corner fittings at each corner of the outboard modules. On the extreme outboard corners, fenders can be substituted for these removable corner posts. It will still be necessary to have ISO corners on the center module to meet support and stacking requirements aboard ship. Because an assembled Tri-Module will exceed 30 long tons in weight, secondary lifting points will be required.

A key feature of the Tri-Module is the connection system that connects the two outer Tri-Module units to the center unit. These connectors are installed dockside, prior to hoisting the Tri-Module aboard the designated transport ship. The basic Tri-Module concept and the type of interconnect fittings are discussed in more detail in the Phase I Final Report (reference 1).

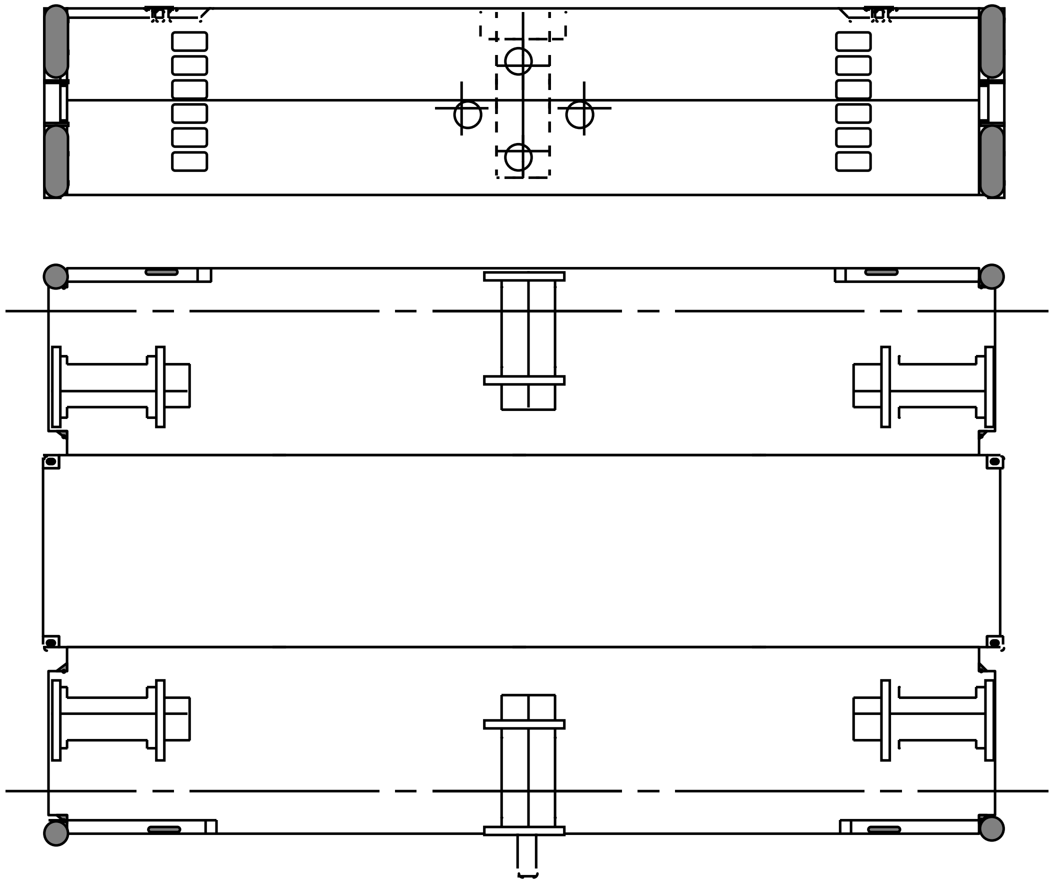


Figure 2-1 ACBL Tri-Module concept has a center module with fixed ISO corners and port and starboard modules housing ACBL RCA units

3 INTEGRATION OF NAVY CONNECTOR SYSTEM WITH THE TRI-MODULE CONCEPT

The Navy connection system uses a rigid connector assembly for connecting modules together and a flexible connector assembly for connecting assembled causeway sections. Preliminary information on this system, which is still under development at NFESC, was provided in several concept drawings. Further information was obtained during the interim meeting held at NFESC on 28th March 1989.

3.1 Rigid Connector Assembly (RCA) Design Concept

The Navy supplied drawings and information on the RCA show the connector system installed on a monolithic ACBL structure 40-ft long by 24-ft wide by 8-ft high and the general size and operation is apparent. The RCA is slid vertically into the structure and is located by two vertical bars on each side. These bars would react horizontal tension and compression loads and moments in the horizontal and vertical planes. The RCA is retained by two members across the top. A plate fits over the RCA to provide a flush deck. The two top bars carry the shear or tension loads across the large cut-out necessary to house the RCA. The bars also react any vertical loads transmitted through the connector system.

The ACBL monolithic structure concept comprises three ACBL modules; a rectangular center section sandwiched between raked end sections. Each module is 40 feet long by 24 feet wide making the total lighter 120 feet long by 24 feet wide. The end rakes are connected to the center module with two connector systems whose centers are 7 feet either side of the module centerline. There is also a connector at the midpoint of each side of each module. These features are illustrated in Figure 3-1, below.

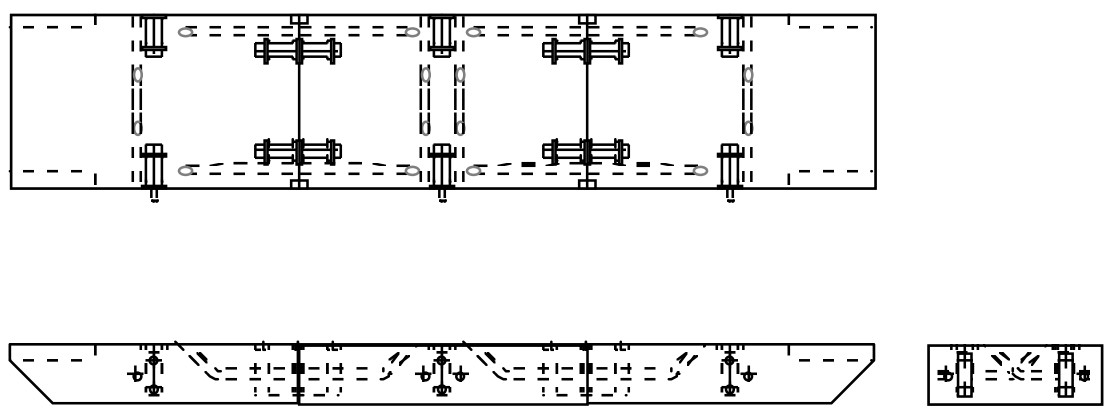


Figure 3-1 The Monolithic ACBL concept calls for three modules to be connected together to form 120-foot long by 24-foot wide lighters

In addition to the connectors there are flexible alignment pins that slide into tubes located at mid-module height with their centers 2-1/2 feet from the centers of the connector. For the end RCAs the alignment pins are outboard of the connectors on 19-foot centers. For the sides, the alignment pin tubes are towards the raked ends on the rake end modules and each side of the connector for the middle modules. The lighters can be joined side-to-side with these alignment pins and connectors. The lighters can be joined end-to-end with large flexible connectors that combine the characteristics of the flexible alignment pin with a hinged rigid member.

3.2 Integration of Navy RCA with Tri-Module Concept

As part of this study the design of the RCA was fitted into the Tri-Module concept design and evaluated with regard to form, fit and structural implications. Figure 3-2 shows the RCA located in side and plan views on the ACBL Tri-Module concept.

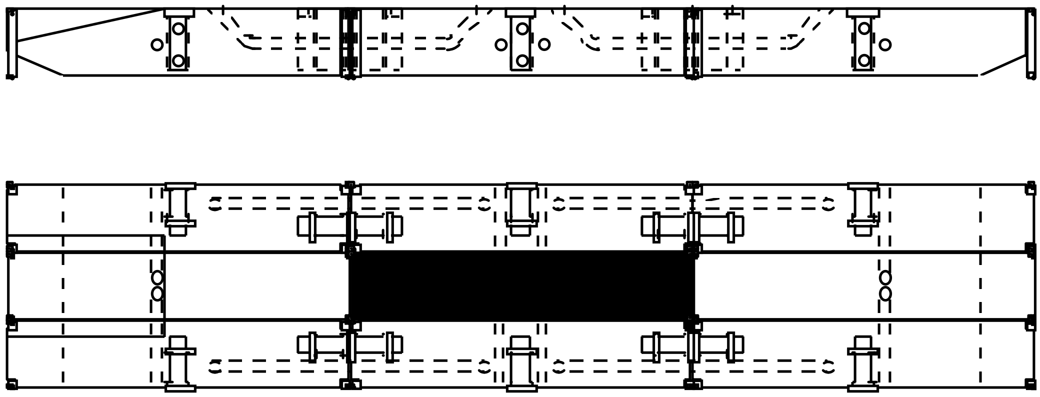


Figure 3-2 Navy designed connector system arranged on Tri-Module ACBL

As the RCA was originally designed for the monolithic ACBL concept there are several areas that will need to be refined for the system to work efficiently with the Tri-Module concept. While recognizing that the RCA is at an early stage of development, some general observations and comments regarding the design as they relate to integrating with the Tri-Module design concept are appropriate. These are briefly discussed in the following paragraphs.

One concern involves the vertical separation of the connector pins which is only 4 feet despite the fact that the modules are 8 feet deep. This means that the tensile and compressive loads due to bending will be relatively high and require heavier back-up structure to distribute these loads into the hull. If this separation were increased, the loads could be better distributed into the top and bottom plates of the module. The two top bars on the RCA appear to be the only structural members that can carry any shear or tension loads across the large cut-out necessary to house the RCA. The bars must also react any vertical loads transmitted through the RCA. Having such a large cut-out, particularly in the middle of each side, creates a significant structural problem. Each side Tri-Module unit becomes almost two separate modules joined only by the structure around the side connector module. To carry the loads transmitted by the connectors in the ends, and to react the longitudinal bending loads generated by the hydrodynamic loads acting on the module, it will be necessary to incorporate a major longitudinal load beam, built around the end connectors. Transverse frames must collect the substantial deck loads and transfer them to this beam. The center modules however, can be of a more uniform and efficient structural design.

To fit the RCA to the Tri-Module presents a number of detail problems. The first of these is the length of the tubes for the alignment pins. It can be seen in Figure 3-3, that the tubes cross and extend a little beyond the nominal 8-foot Tri-Module interface. It should be possible to shorten the tubes and to make tubes align in adjacent modules. However, it is not considered practicable to have the tubes intersect each other.

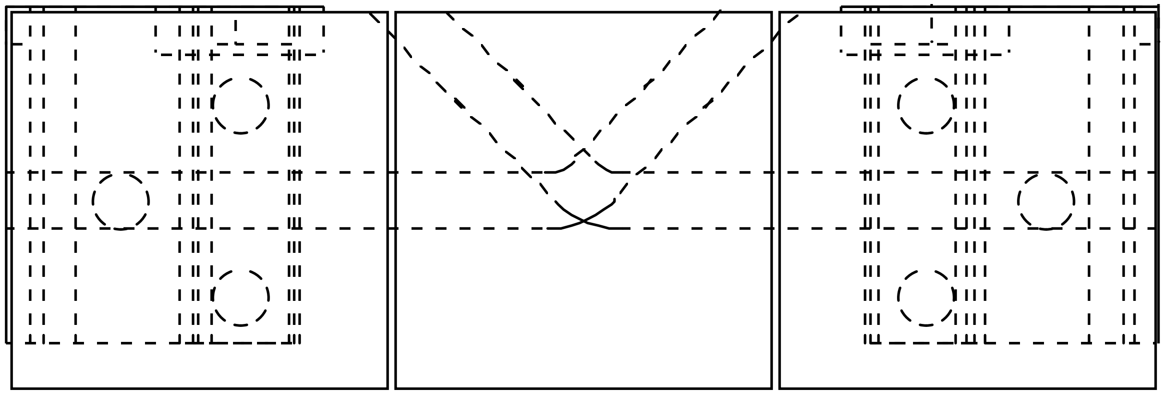


Figure 3-3 Alignment Pin tubes conflict with each other and Tri-Module boundaries

For the purpose of designing the desk-top model (reference section 8. below), the tubes have been arbitrarily shortened. An alternative approach would be to change the angle of the tube to avoid this problem. This may not be consistent with actual operational requirements and the conflict must be more properly resolved during future design studies.

A key feature of the Tri-Module concept is that removable ISO corners are fitted to the outer modules and fenders can conveniently be fitted in place of the removed outer ISO corners. The location of the large flexible connectors at the extremities of the ACBL modules is not compatible with the Tri-Module concept. They would have to moved further inboard, to align with the connector modules at the square ends.

Another feature of the Tri-Module concept is that strong, permanently installed mooring and towing cleats are integrated in the structure, flush with the deck so that they are always available. Some slight modifications of the position of the connectors will have to be made in order to accommodate these features.

Based upon the studies conducted here it is believed that the RCA units can be integrated with the Tri-Module structure providing the concerns discussed in the preceding paragraphs are properly addressed.

4 ACBL TO NL/MCS RAMPS

A specific task for this study was to develop concepts of ACBL to NL or MCS interface ramps. The interface ramp is necessary for several reasons not the least of which is the need to provide a transition from the current lighterage platform systems (i.e. NLs and MCS) as the ACBL is integrated into the Navy’s inventory. The variation in deck height is the obvious problem requiring a ramp from the ACBL down to the lower platform with a ramp angle not to exceed 12 degrees. However, the need for an interface ramp is not the only problem. There is still a general problem in interfacing any lighter to any other in that if the lighters are not trimmed so that the connectors are at the same level, they are difficult or impossible to connect. It would not normally be expected to connect an ACBL section to an MCS or an NL to form a ferry, but it could well be that one type of section would be used as a platform or pier and the other type would need to interface with it to load or unload. To meet this need it would be highly desirable to have a means on the ACBL of adjusting the height of the NL type interface connection regardless of load or floating trim.

MJP&A have developed four basic design concepts for a combined interface ramp and connection system between the ACBL and NL/MCS platforms. These concepts are briefly described in the following paragraphs along with trade-off discussions.

4.1 Filler ramp using ball and socket type connector

A combination connector, that fits both the Flexor receiver and the ACBL alignment will make the ACBL interoperable with the NL/MCS lighters. The mid-height location in the ACBL will match the heights of the NL/MCS Flexors when the various lighters are afloat. To enable vehicles to drive from one vehicle deck to another a simple filler ramp can be designed that will match the differences in deck height and be within the limits of break angle (Approximately 12 degrees). The concept is illustrated in Figure 4-1, below.

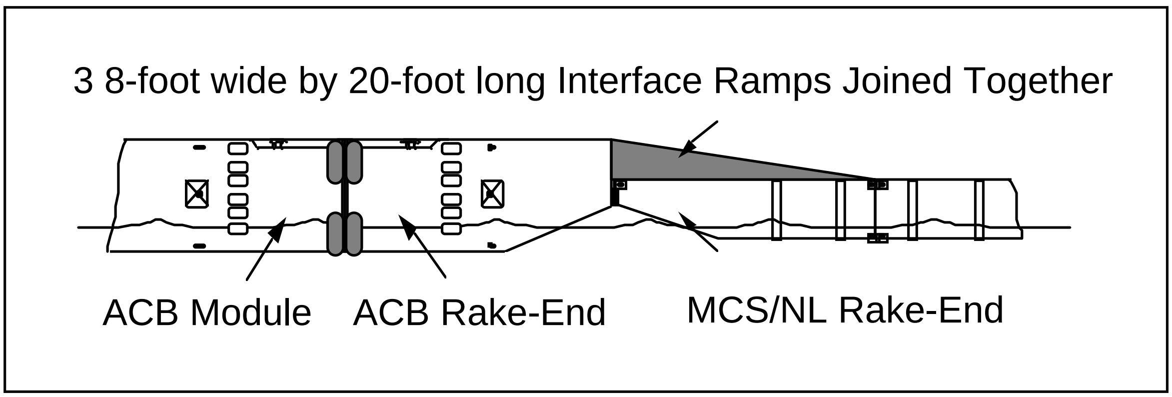


Figure 4-1 Simple filler ramps make up for differences in deck height

The structural concept will be simple as the deck will be similar in configuration to the decks of the ACBL or the MCS as it has to carry the same wheel loads (including that of a RTCH carrying a container). The supporting structure has only to carry the direct loads between the ramp deck to the NL/MCS lighter deck. The ramp can be made in 8-foot widths and secured to the lighter deck. A single offset flush lifting ring can be positioned in each width so that they will hang level when lifted. If they are made as sealed modules, they would not sink if dropped overboard. Alternatively, an open structure would be easier to maintain to prevent corrosion. Although shown as a complete filler, a gap would be left between the filler pieces and the end of the ACBL to allow for relative movement. Hinged plates, attached to the filler pieces, would provide a continuous deck surface. Initially this method appeared to be a simple relatively low-cost solution. However, this concept was rejected for the following reasons.

a) The problem with the combination connector, that fits both the Flexor receiver and the ACBL alignment, is that the NL/MCS Flexor housing was not designed to take the shear loads that would be experienced in an all-in-one type of connector. The Navy already has problems surviving normal loads on the connection system because of the increasing age of the NL inventory. It would not be practical or cost effective to modify the existing inventory of NL/MCS to meet the requirements of the interface ramp.

b) The ramp as presented in Figure 4-1 would require that each MCS/NL causeway ferry would have to be outfitted with this ramp if it is to be fully interoperate with an ACBL RRDF. If another ship were using an MCS RRDF, the causeway ferries equipped with this ramp wouldn't be usable at those off load points.

4.2 Special 20-foot ACBL/MCS/NL Interface Modules

This concept illustrated in Figure 4-2, consists of a 20-foot long module that has ACBL connectors at one end and NL connectors at the other. A transition is made from the ACBL deck height to the NL/MCS deck height with a sloping deck. Two such modules could be joined nose-to-nose so that they occupy a standard 40-foot container space. The modules could be assembled dockside from three 8-foot wide modules in the same manner as the Tri-Module for ease of inter modal transportation and handling. This method showed promise but presented special handling problems discussed below.

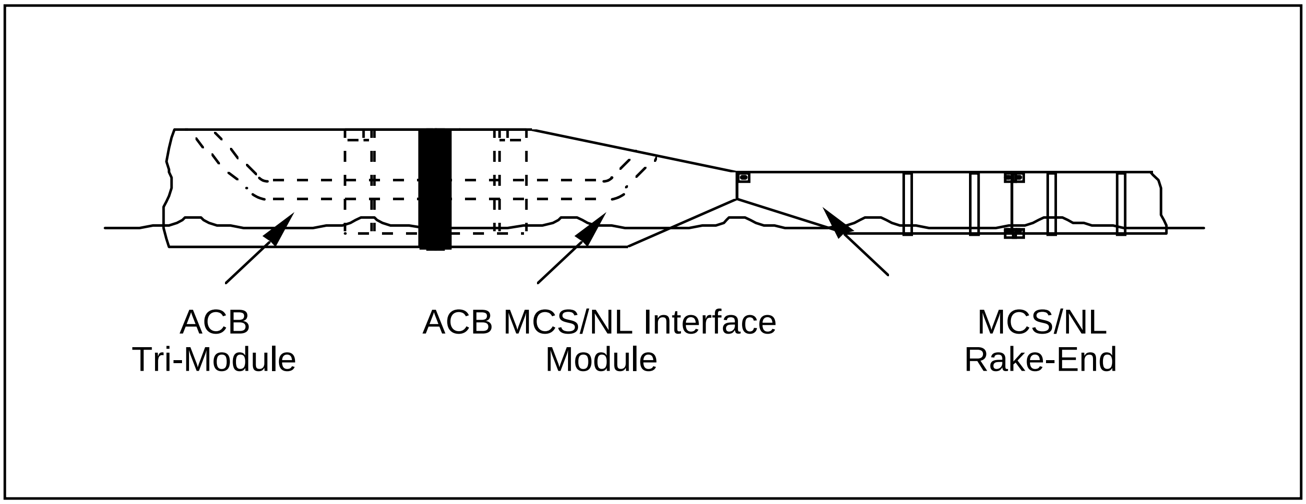


Figure 4-2 Two Special 20-foot ACBL/MCS/NL Interface Modules can be stowed nose-to-nose in a 40-foot container space

a) The twenty foot special ACBL-NL/MCS module would not be able to house the side RCA in a position compatible with 40-ft modules which would present difficulties interfacing with various platform configurations.

b) Managing the 20-ft module in high sea states (i.e. prior to mating with a 40-ft module) could present significant problems.

4.3 Special 40-foot ACBL/MCS/NL Interface Module

The interface ramp concept illustrated in Figure 4-3 (and in Drawing No. MJP&A/ACBL/019) is somewhat similar to the 20-ft concept discussed under paragraph 4.2 above except that it is based on 40-foot long modules. This module would appear

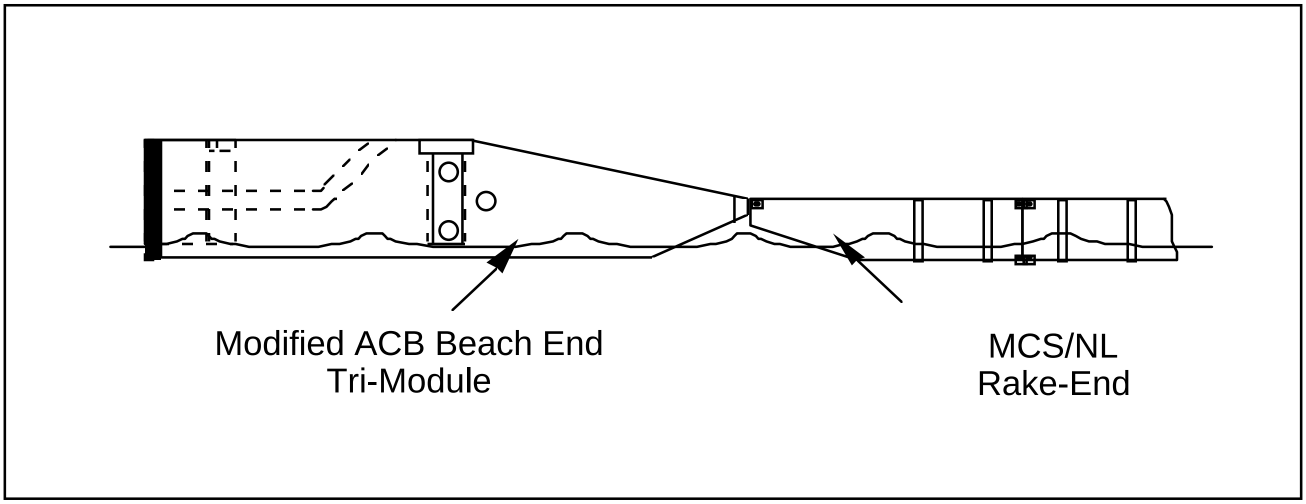


Figure 4-3 A Special 40-foot ACBL/MCS/NL Interface Modules can be fitted with ISO corner posts and stowed in a 40-foot container space

similar to a Beach End ACBL (see Section 5. below) with its beach ramp removed. The sloping deck would actually be full width running from the ’midship Navy connector to an NL connector system. It could also be made as a Tri-Module for ease of inter modal transportation and handling. The removable ISO corner posts would have to be supported rather differently as the NL connector system must be installed within the overall length limitations of ISO containers. However, because of its asymmetry, the centers of gravity of the individual Tri-Modules may be beyond the limits allowed for handling as an ISO container.

4.4 Special 40-foot hinged ACBL/MCS/NL Interface Module

This concept is a derivative of the 40-ft interface ramp discussed in paragraph 4.3 above. A separate, compartmented nose section is hinged at the lower deck. It could be arranged to hinge and provide a mechanism to tilt the whole end of the special ACBL interface module. The range of adjustment is illustrated in Figure 4-4. With less than 10 degrees of articulation, a 2-foot range of vertical adjustment could be achieved. This would cover a wide range of disparate loading or trim conditions. With the hinge at the lower surface of the module, the gap at the deck could be covered with simple hinged deck plates.

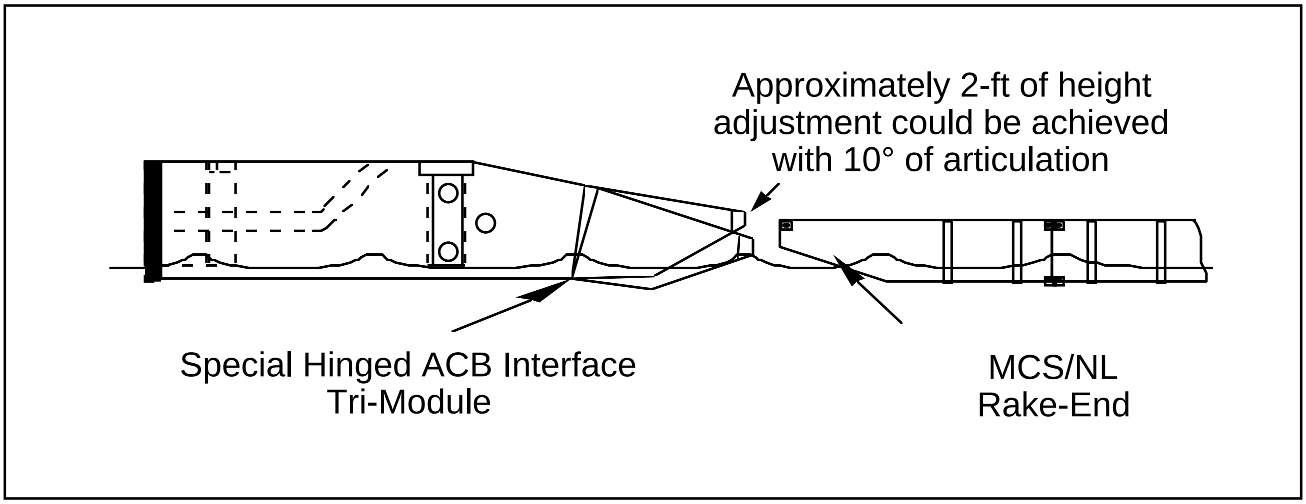


Figure 4-4 A Special 40-foot hinged ACBL/MCS/NL Interface Module could provide 2 feet of vertical height adjustment

This concept shows promise but adds yet another layer of complexity on the overall system which must be considered in terms of system reliability and cost factors versus the utility of the system.

A review of the concepts discussed in this section suggests that the special 40-ft module design (reference figure 4-3 paragraph 4.3 above) with integrated interface ramp and ACBL to NL/MCS connectors is the preferred solution.

5 ACBL BEACH INTERFACE RAMP

A concept of a special beach-end Tri-Module was shown at the interim meeting. It had a 25 degree rake to the module end, and a beach interface ramp pivoted at mid-height as illustrated in Figure 5-1, below (Note: also illustrated in drawing No. MJP&A/ACBL/018). The ramp would be in three sections. A center 8-foot wide section would be hinged to the center Tri-Module. Two 2-foot 9-inch sections would be hinged to the outer modules, one each side, and be rotated by mechanisms in the outer portions of the outer modules. On assembly dockside, the two outer sections would be connected to the center section to form a one-piece, 13-foot 6-inch wide ramp. This width will be sufficient for all vehicles with approximately 9 inches of clearance on either side for the 12-foot wide M1 tank. The ramp will be rotated forward on reaching the beach. The dual ramp operating systems, (i.e. one on each side) will be designed so that the ramp can be deployed using just one actuator. It is anticipated that the rotation system will be hydraulically powered or could be mechanically operated if no power is available. The plan view of the beach end ramp Tri-Module with RCA units in place is illustrated in figure 5-2.

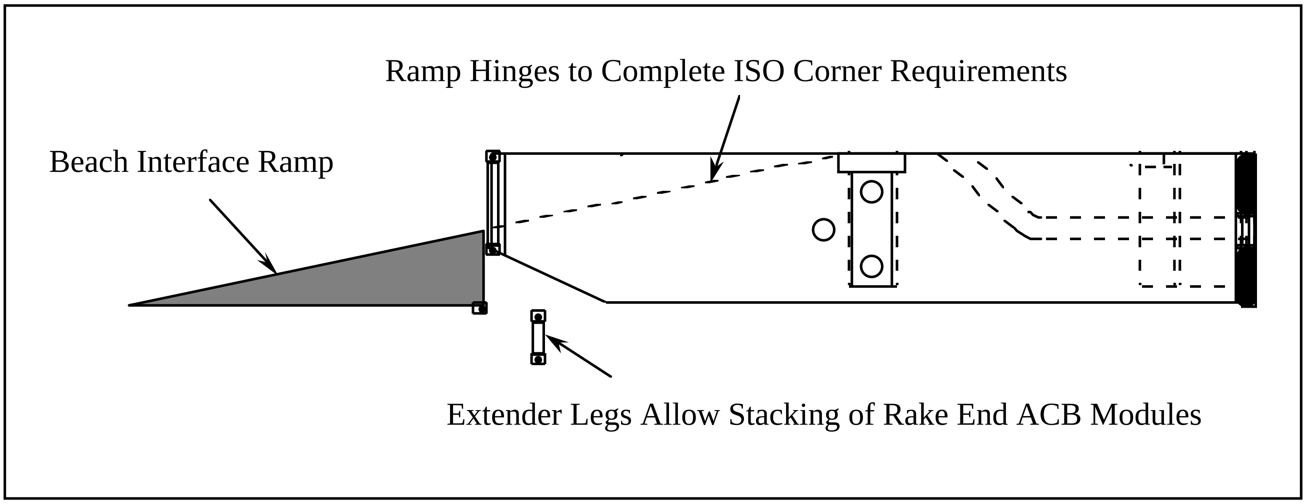


Figure 5-1 Beach Interface Ramp concept using a rake angle of 25°

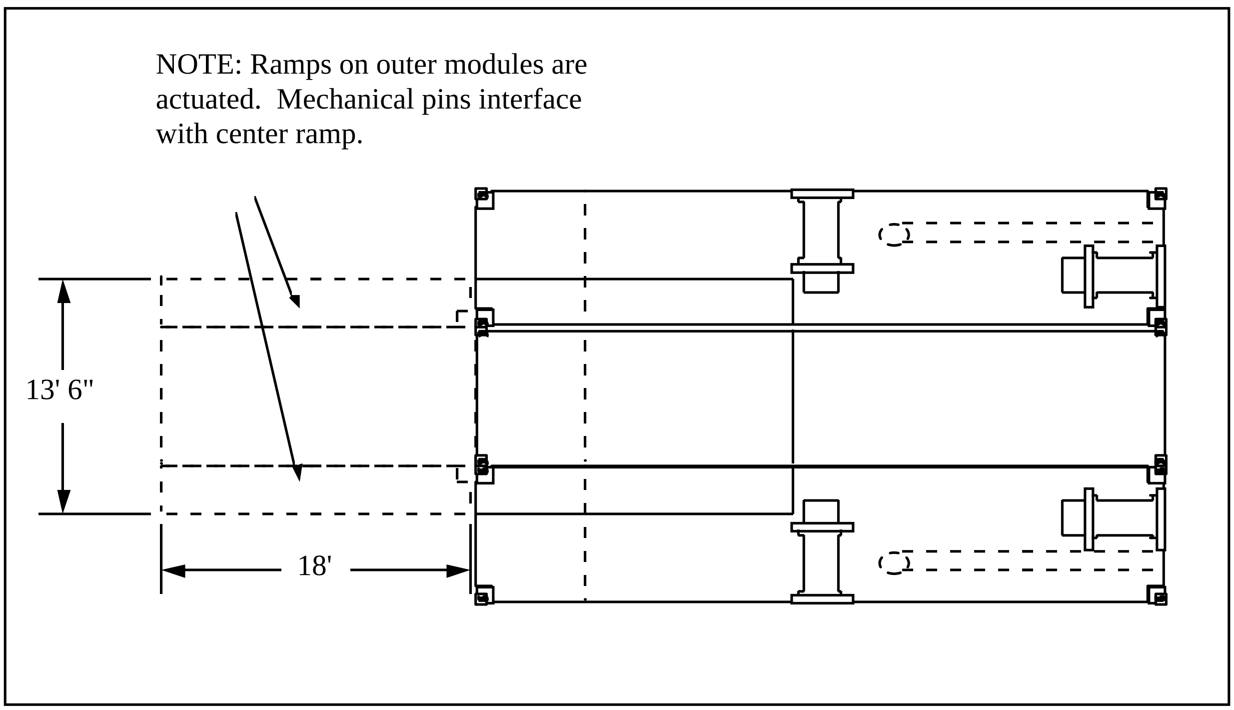


Figure 5-2 Plan view of beach ramp located on special 40-ft raked end Tri-Module

A structural analysis has been conducted to size the structural elements needed to carry the heavy wheel loading of the RTCH carrying a container. The top deck structure will be similar to that of the Tri-Modules, but will be supported differently because of the nearly 20-foot length between the hinge support and the ramp tip resting on the beach. High longitudinal stiffness will be required to carry the bending loads. If the ramp cannot be configured with its hinge at least approximately half height, then it will have to be in two of more lengths with additional hinges. Such a configuration is inherently weaker and it would be very difficult to design it to carry the desired loads.

A preliminary structural design and weight analysis has resulted in a weight estimate of 15,000 pounds for the ramp, excluding its operating mechanism. The assumed load condition was that of a RTCH carrying a container down the ramp with its tip supported by the beach. A longer span, or a double folded ramp would weigh even more. This structural and weight analysis of the Tri-Module beach-end ramp is included as part of Appendix A.

6 OTHER FEATURES AND DESIGN CONSIDERATIONS

The ACBL Tri-Modue will need to have other special features such as a mooring/towing bitt arrangement built-in flush with the deck in each corner of the outer Tri-Modules and built-in, flush boarding ladders. Ancillary systems are also required such as deck winches to pull in the alignment pins, deck tie-down fittings, access hatches, and possibly safety rails but these have a less significant effect on the structural arrangement and can be defined during future design phases.

The special connector fittings for attaching the outer Tri-Module units to the center unit are also considered a special feature of the Tri-Module concept. These connectors would normally be installed or removed at a dockside facility with ISO container handling facilities. This connector design is considered part of the next design phase and should be addressed in some detail to achieve an efficient design capable of transferring the loads between Tri-Module units and being rapidly and reliably assembled or disassembled dockside.

When the three Tri-Module units are assembled into a complete Tri-Module (i.e. 40-ft x 24-ft x 8-ft) the total assembly weight will exceed the 30 long ton lifting capacity of the single boom cranes (e.g. Hagglund cranes aboard T-ACS auxiliary crane ship). A twin boom lift will be required along with a special harness to lift the Tri-Module in and out of the container hold. A special set of lifting points will be required to lift the Tri-Modules which will be located along the interface between the inner and outer Tri-Module units. An analysis of the structural requirements of these fittings and their suggested location is presented in Appendix A to this report.

7 STRUCTURAL CONSIDERATIONS

In the Phase I study (see reference 1), the major loads considered were those due to operation of a Rough Terrain Container Handler (RTCH) on the deck of the lighter. This imposes very high local loads requiring a well reinforced deck structure with substantial supporting framework. The previous structural analysis sized the transverse frames to meet these high deck loads. Since some of these structural elements conflict with the RCA, they must be revised to provide alternative load paths. A more detailed structural and weight assessment is included as Appendix A. The analysis of the Beach-End Ramp is also included in Appendix A as described above.

Bottom loads, which equal the weight of the structure and its payload when floating in calm water, are well distributed. When sitting on uneven ground such as a rocky beach, local loads will be much higher. Also, when operating in longer waves typical of Sea State 3, hogging and sagging loads on the 120-foot long lighter will create significant bending moments, particularly in the middle of the middle module. This is also where a RCA unit has been located. The nominal 2-foot wide by 6-foot deep by 7-foot cutout required to accommodate the RCA will require appropriate reinforcement so that these high bending moments and other loads may be carried around the cutouts. A preliminary structural analysis of this area has been conducted and is included in Appendix A. The 8-foot deep truss formed by the module side is well able to carry the bending loads providing the RCA beam at the outer edge can be adequately connected to the module’s edge members. The second inboard transverse member indicated in the drawings provided by NFESC will not serve much purpose on the Tri-Module design as there will be nothing significant to connect it to.

Note that the inside of the cut-out must be plated all around to maintain watertight integrity. The plating would be simpler if the vertical rails were incorporated in the cut-out and the corresponding grooves were made in the RCA. Also note that two sets of vertical rails are redundant and load paths become indeterminate. To ensure say equal division of load between two sets of rails, they and the corresponding grooves would have to be machined to close tolerances and they would have to have equal structural stiffness. Again it would be simpler to eliminate the inboard set and make the outboard set react directly with the outboard module structure. This would make the load paths within the RCA more determinate. The major loads will pass through the retaining guillotine and its supporting structure which is conveniently located nearer to the outboard set of rails.

During the Phase I study a preliminary weights analysis of the Tri-Module system was developed and presented in Appendix B Tables 8 & 9 (see reference 1). A total weight for the Tri-Module was estimated at approximately 42.75 long tons. Based upon the preliminary structural analysis presented in Appendix A to this report, the weights of the removed and added structure needed to accommodate the RCAs have been estimated to be of the order of 3500 pounds for the side connectors and as much as 4500 pounds for the end connectors. This does not include the weight of the RCAs nor the alignment pins and their required additions to the module structure. It should be emphasized that at this stage of the design the weight analysis must be considered rudimentary at best and will require an extensive detailed analysis during the next phase of design to arrive at a reasonable estimate.

8 DESIGN AND FABRICATION OF 1/35-SCALE MODELS

To enable representatives of the Navy to more graphically illustrate the features that might be incorporated in a Tri-Module form of the ACBL it was requested that MJP&A design and construct a series of models that could be easily transported and shown in a desk-top presentation. It was decided that a 1/35th scale would be appropriate. Each 40-foot long by 24-foot wide by 8-foot deep ACBL module would be approximately 14 inches long by 8 inches wide by 3 inches deep. Three modules, assembled to represent a 120-foot long ACBL lighter would be just over 40 inches long and fit on a desk. The 1/35th scale was also selected because a great many commercially available model kits are produced at 1/35th scale. Two kits of M-1 tank models were purchased and assembled to better illustrate the size of the ACBL lighter. The 1/35-scale model is shown on sheets 1 & 2 of a "D"-size Drawing No. MJP&A/ACBL/021.

A major feature to be represented was the use of three ISO-container sized modules that could be joined together to form the 24-foot wide ACBL module. The center module of each set of Tri-Modules would have conventional, fixed ISO corners. The outboard modules would each have four removable corner posts with ISO corners at their top and bottom ends. To illustrate the transport and assembly of the Tri-Module ACBL, the separate modules, with the ISO corners all in place, would be taken from their carrying case and placed upon the table. The ISO corner posts of the outer modules would then be removed and the sets of three modules connected together with the aid of simple dowels to form Tri-Modules.

At such a small scale it was not feasible to include such small detail as the modeling of the actual means of attaching/detaching the ISO corner posts, or the actual means of bolting the modules together. To make the fitting of the corners more understandable, a larger scale model (1/12th full size) of a single corner post and its attachment was fabricated. Even at this scale it was still not possible to make an exact representation.

Having assembled the basic Tri-Module, representations of fenders are added to the corners of the Tri-Modules. The fenders would be attached/detached in the same manner as the corner posts. The arrangement of the 1/12-scale corner is illustrated in the sequence shown in figure 8-1. First with the ISO corner posts fitted, then with the posts removed and finally with the fenders fitted. The RCA units are represented in a very simplified manner. The locations and style of the RCA units are indicated. Also the Alignment Pin Receivers, the tubes used to contain the Alignment Pins, are shown. Simplified pins have been included in the ends of the Tri-Modules to illustrate their operation. Again, because of the small scale, it is not feasible to model the actuation of the RCA. The details of the RCA are being developed and evaluated under in-house Navy studies and data from those studies are best used to show the benefits of the system.

A square ended Tri-Module is used at the center of a 120-foot ACBL. At each end the modules are raked to improve their hydrodynamic characteristics. In the original Navy concept, the ends were raked at 45 degrees, but to be compatible with MJP&A's beach ramp concept, the end rake angle has been reduced to just 25 degrees. A beach end version as well as a simple raked version of the Tri-Module has been modeled. These three ACBL Tri-Modules, when placed end-to-end, represent a 120-foot long ACBL.

The beach ramp is in three parts. The center module has been sliced off at 12 degrees from the mid-height of one end up to the deck. This triangular sectioned piece is hinged to the end of the module and may be rotated 180 degrees to form a continuous ramp to the beach. Each of the outer modules has a similarly sectioned piece cut off, but only representative of a 2-foot 9-inch wide ramp. When the three modules are joined together, pieces of dowel are pushed through the three sections of ramp to make a single piece. The full-scale ramp would be 13-foot 6-inches wide. The center 8-foot width plus a 2-foot 9-inch width on either side. The outer 5-ft 3-inches of each side module would contain the actuation mechanism. The model is too small to include self-actuation. The full-scale ramp would undoubtedly be fitted with traction bars and the deck would have some pattern of tie-down fittings and other details.

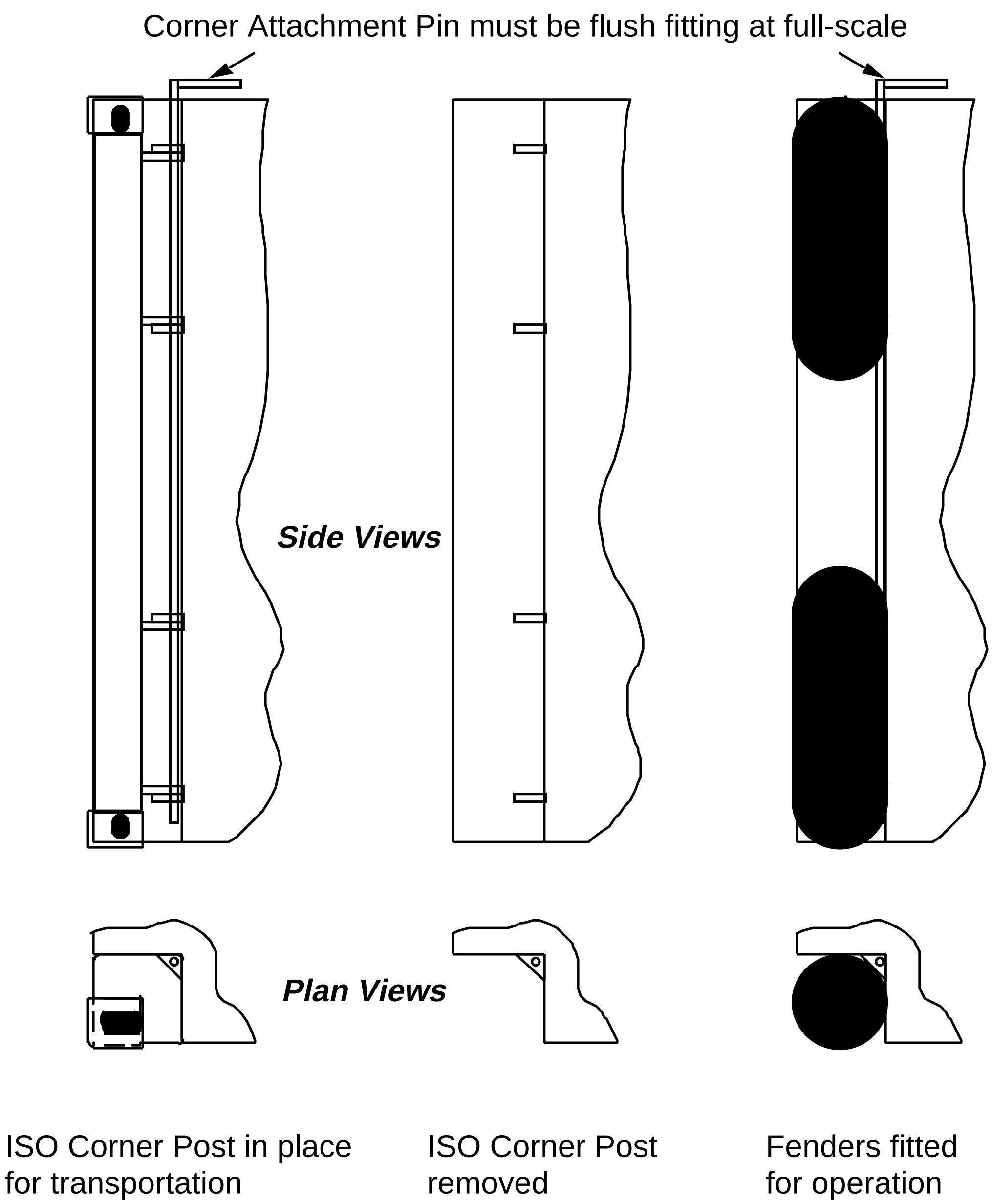


Figure 8-1 Transportation ISO corner posts are removed on assembly as Tri-Module and fenders fitted at outer corners

Flexible connectors are to be fitted to rake ends to allow one ACBL to be flexibly attached to another ACBL module. The Navy-supplied information on these flexible connectors showed that they were to be fitted in the outboard corners of the ACBL. This arrangement would not allow the inclusion of the removable ISO corner posts. For the purpose of the Tri-Module module, it was agreed that the flexible connectors could be moved inboard. It was further agreed that their centerlines could be aligned with the centerlines of the RCAs fitted at the other end of the module. This change also allowed the fitting of the recommended fixed mooring/towing cleats. Just the openings for the flexible connectors are shown on the model.

A series of photographs of the 1/35th scale ACBL Tri-Module are presented under Appendix C to this report.

9 CONCLUSIONS AND RECOMMENDATIONS

As previously stated, the development of the Tri-Module concept presented in the Phase I study grew out of the difficulties encountered trying to meet the 30 long ton weight limitation of a 40-ft by 24-ft by 8-ft high monolithic ACBL module and the problems associated with handling and transporting such large structures. This Phase II study was aimed at broadening the Tri-Module concept in general and integrating specific systems such as the RCA and loading ramps. The conclusions and recommendations from this study are presented under the following paragraphs.

9.1 Integration of Rigid Connector Assembly (RCA)

It is MJP&A’s opinion that the RCA as designed, developed and tested at model scale by NFESC can be integrated with the Tri-Module concept. However, as discussed in paragraph 3.2 above, there are several fundamental areas of the design which need close attention for the integration to be successful. Of particular importance is the need for a clear definition of the loads and load transfer paths from the RCA units through the Tri-Module structure. It is recommended that this area be given a high priority for future studies. The development of a Finite Element Model (FEM) and subsequent analysis of the RCA and surrounding structure would be extremely useful to refine structural requirements and thereby develop a more realistic weight analysis of the components.

MJP&A recognizes that NFESC have carefully studied the requirements for the RCA and have conducted rigorous trade-off analyses of the various connector designs conceived during the ACBL connector design studies (e.g. reference 2). However, as the Tri-Module concept is a departure from the original ACBL design approach (i.e. the monolithic 40-ft x24-ft x8-ft structure) it is recommended that alternate connector concepts be re-evaluated for their merits relative to this (Tri-Module) design. This is particularly relevant given the relatively high weight of the current RCA baseline system and the desire to maintain a high level of structural integrity throughout the Tri-Module system.

9.2 Design of ACBL to NL/MCS Interface Ramp

The interface ramp between the ACBL and the current lighterage systems is an important component of the overall system if the ACBL is to be used with current inventory. As such it requires a special adapter module that provides not only a ramp from the 8-ft high ACBL down to the 5-ft/4.5-ft deck heights of current lighters but also a flexible connector compatible with these systems. MJP&A recommends the 40-ft special module described under paragraph 4.3 above be selected as the baseline approach at this time. This design should be refined during future design studies and tested at model scale to establish operational characteristics of the dissimilar platform configurations.

9.3 Design of the ACBL Beach Ramp

A beach ramp concept has been developed that is compatible with the operational requirements of the ACBL and the design constraints of the Tri-Module concept. The design proposed provides a ramp system integrated within the basic structure of a raked end module. A basic structural analysis has been conducted to confirm the design approach. The system should be capable of being actuated either hydraulically or mechanically to maximize reliability. Future studies should focus on the requirements of the actuation mechanism and methods of reducing overall system weight.

9.4 General Conclusions and Recommendations

It was beyond the scope of this current study to develop a realistic cost model of the ACBL Tri-Module concept. There is now sufficient design information available to provide the basis for a realistic cost model. Any future cost studies should be integrated with a more thorough weights analysis and materials breakdown.

The interconnect fittings between the inner (center) Tri-Module and outer (port and starboard) units have not been fully defined under MJP&A's Phase I and II studies. These connectors are installed prior to the Tri-Modules being loaded aboard ship. As these connectors are primary load carriers and a major component of the Tri-Module design they should be given careful consideration in any subsequent design studies.

REFERENCES

1. U. S. Navy Amphibious Cargo Beaching Lighter Module Design and Development - Final Report to NFESC, Port Hueneme, CA, dated 3 December 1995 by M. J. Plackett & Associates, Report Number MJP&A:95-014 Contract Number N47408-95-C-0201 contract line item 0001 AD

2. Ocean Module Barge Connection Systems Development - Volume 1 - Conceptual Design & Operating Procedures - Final Report to Naval Civil Engineering Laboratory, Port Hueneme, CA - September 1993 by M. J. Plackett & Associates, Report Number MJP&A:93-003 Contract Number N47408-93-C-7346 CDRL item A004

APPENDIX A

Structural & Weight Analysis

APPENDIX A

Structural & Weight Analysis

Introduction

A series of structural analyses were conducted on various aspects of the Tri-Module design. These included a) a review of the Rigid Connector Assembly (RCA) as designed by the Navy for their monolithic ACBL structure and adapted for the Tri-Module design, b) an evaluation of the loads associated with a beach-end ramp and c) an analysis of the lifting loads for the Tri-Module given that it would exceed the 30 long ton weight limitation. Due to a misunderstanding concerning the required width of the beach-end ramp the basic analysis was conducted on a 12-ft wide ramp instead of a 13-ft 6-inch ramp. This was remedied with a further analysis of the ramp at 13-ft 6-inches wide to confirm the basic load capability and amend the estimated weight.

The structural analyses are arranged in this appendix as follows:

a) Adaptation of structure to Navy Connectors A2 - A8

b) Structural Design of ACB Lighter Ramp A9 - A18

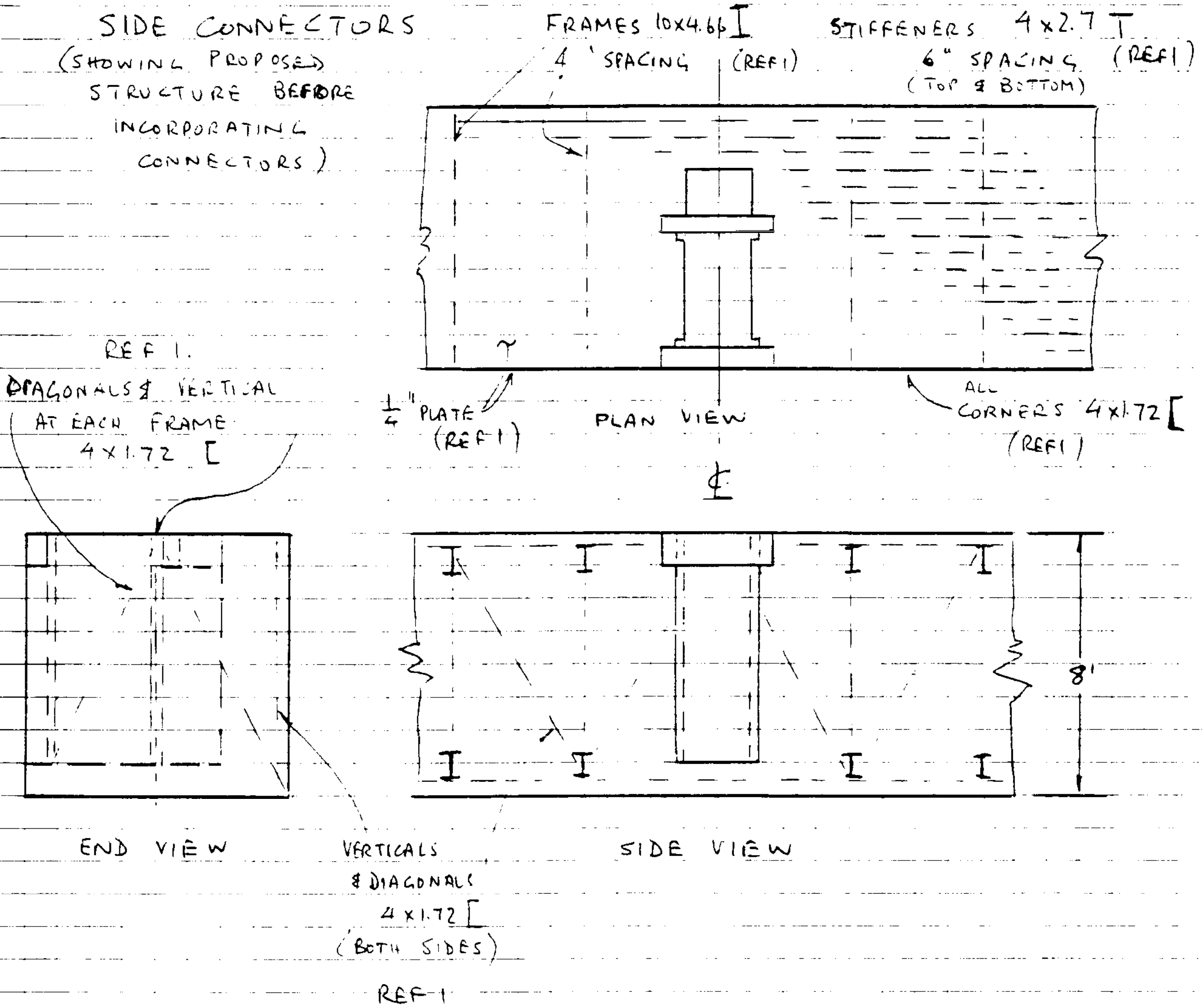
c) Widening of ACB Lighter Ramp A19 - A20

d) ACB Lighter Lifting Loads A21 - A27

AMPHIBIOUS CARGO BEACHING LIGHTER

ADAPTATION OF STRUCTURE TO NAVY CONNECTORS.

1. SIDE CONNECTORS
(SHOWING PROPOSED STRUCTURE BEFORE INCORPORATING CONNECTORS)



SCALE 1:60

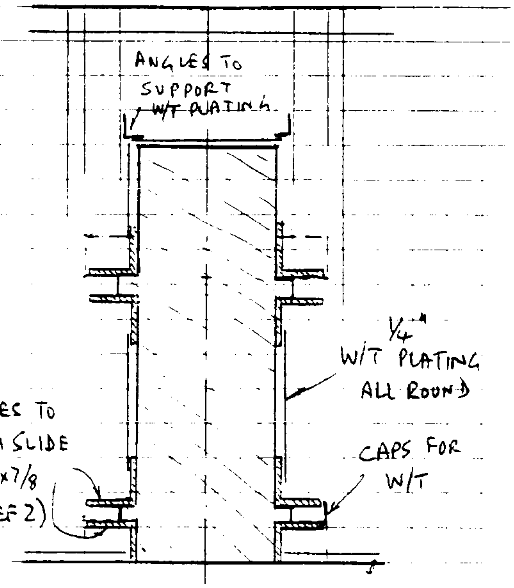
(CONNECTOR GEOMETRY FROM REF 3)

REFERENCES
1: MJP&A REPORT No 95-014 APPENDIX A 3 DEC 1995
2: MEMO E.G.UBAND TO MJP&A, MARCH 27 1996
3. MJP&A REPORT No 96-004 29 APRIL 1996

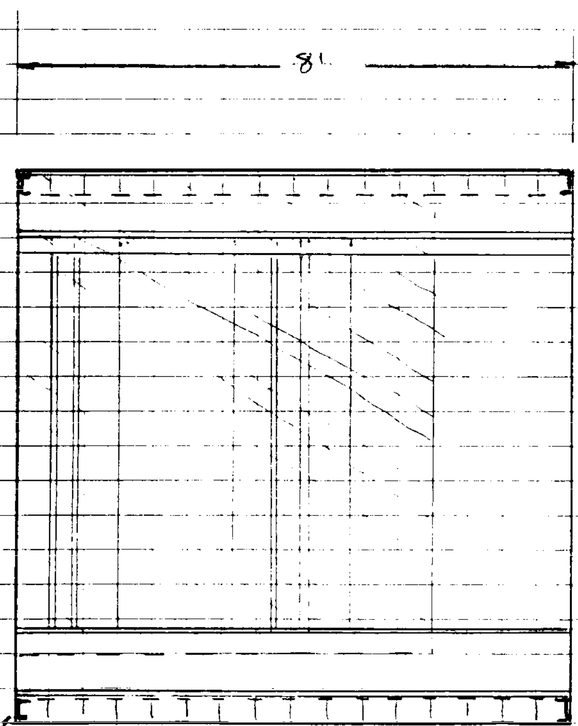
1.1 SIDE CONNECTOR SUPPORT SYSTEM

NOTE: CUT OUT FOR CONNECTOR
MUST BE MADE WATERTIGHT
WITH 1/4" PLATE.

PLAN

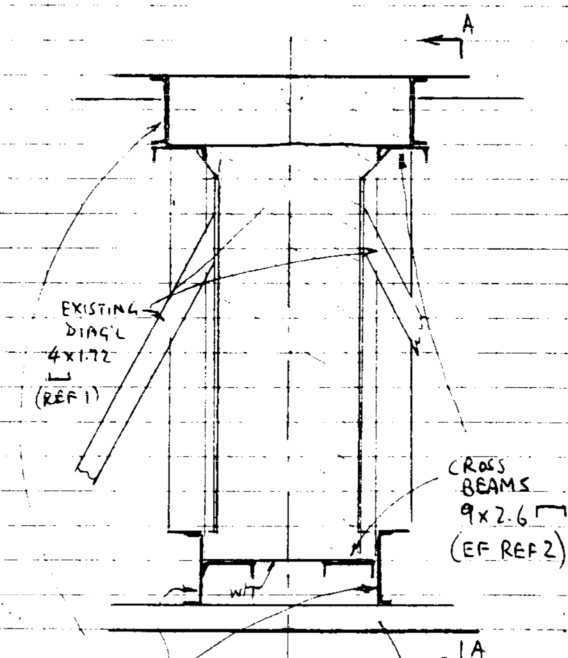


SCALE 1:30



EXISTING CORNER
LONGITUDINALS
4x1.72 [x.32
(REF 1)

END VIEW
(SECTION AA)



REPLACEMENT
FRAMES
] 12x3.047
(REF 1)

EXISTING
PLATE &
STIFFENERS
4x2.7 T
(REF 1)

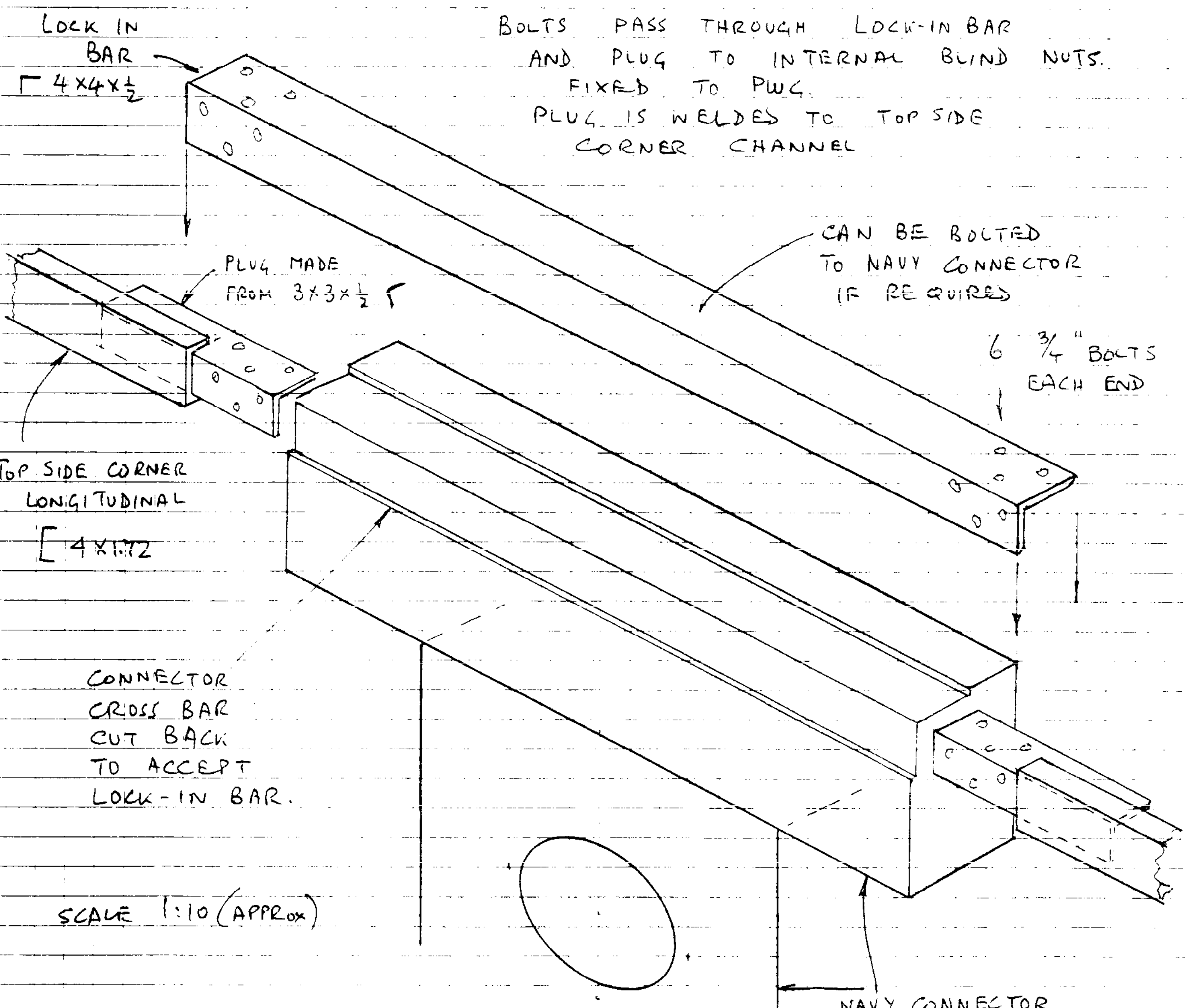
SIDE VIEW
(SIDE PLATING
REMOVED)

1.2 <u>LOCK-IN SYSTEM</u> (FOR SIDE CONNECTOR OUTBOARD END, OTHERS SIMILAR)

LOAD IN LONGITUDINAL CORNER MEMBERS "GH" = 33,500 LB ± (REF 2)

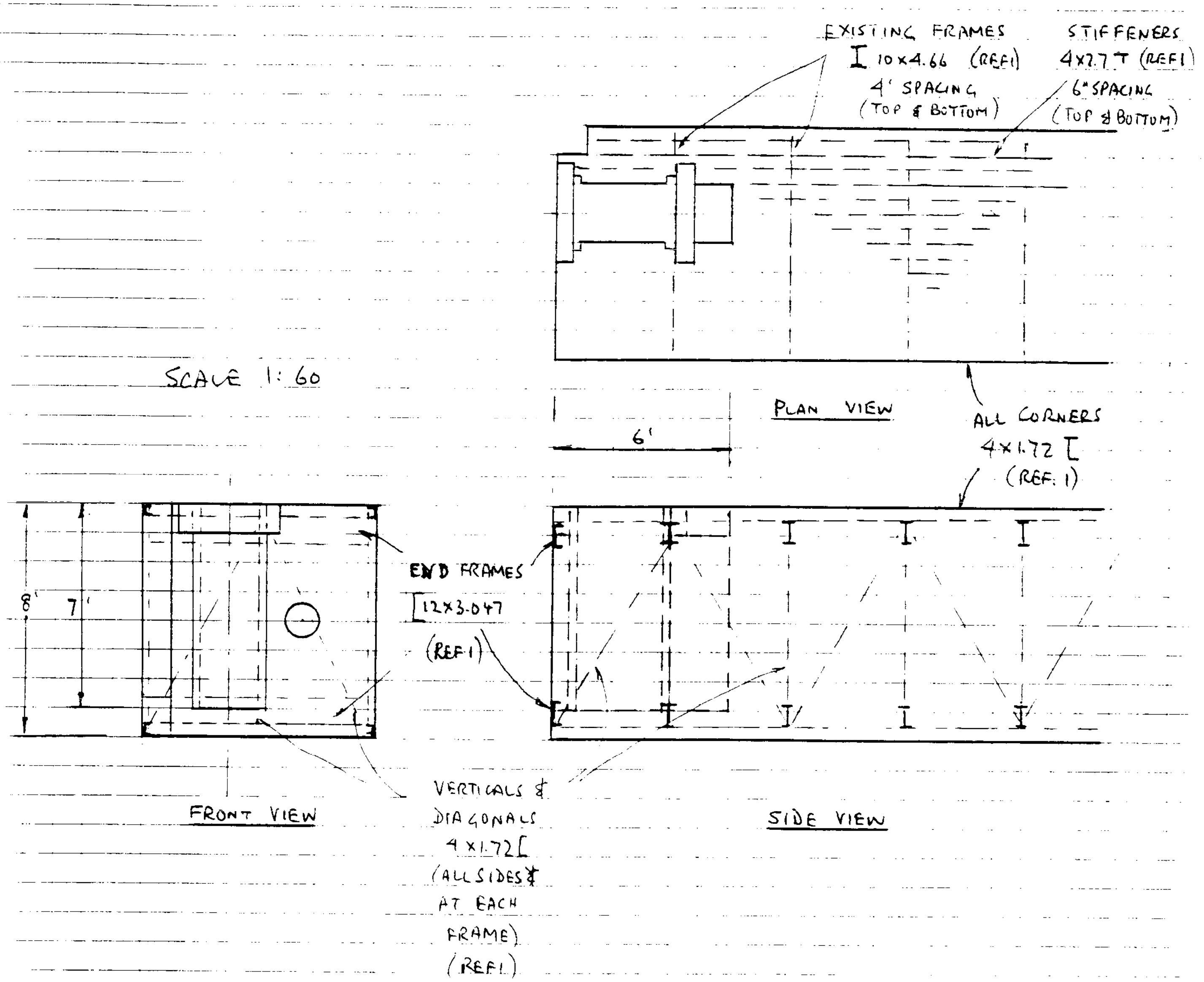
SHEAR STRENGTH OF 3/4" D AM. STD BOLT = 0 LB @ 20,000 psi

THEREFORE USE 6 3/4" D BOLTS AT EACH ~~CONN.~~ END

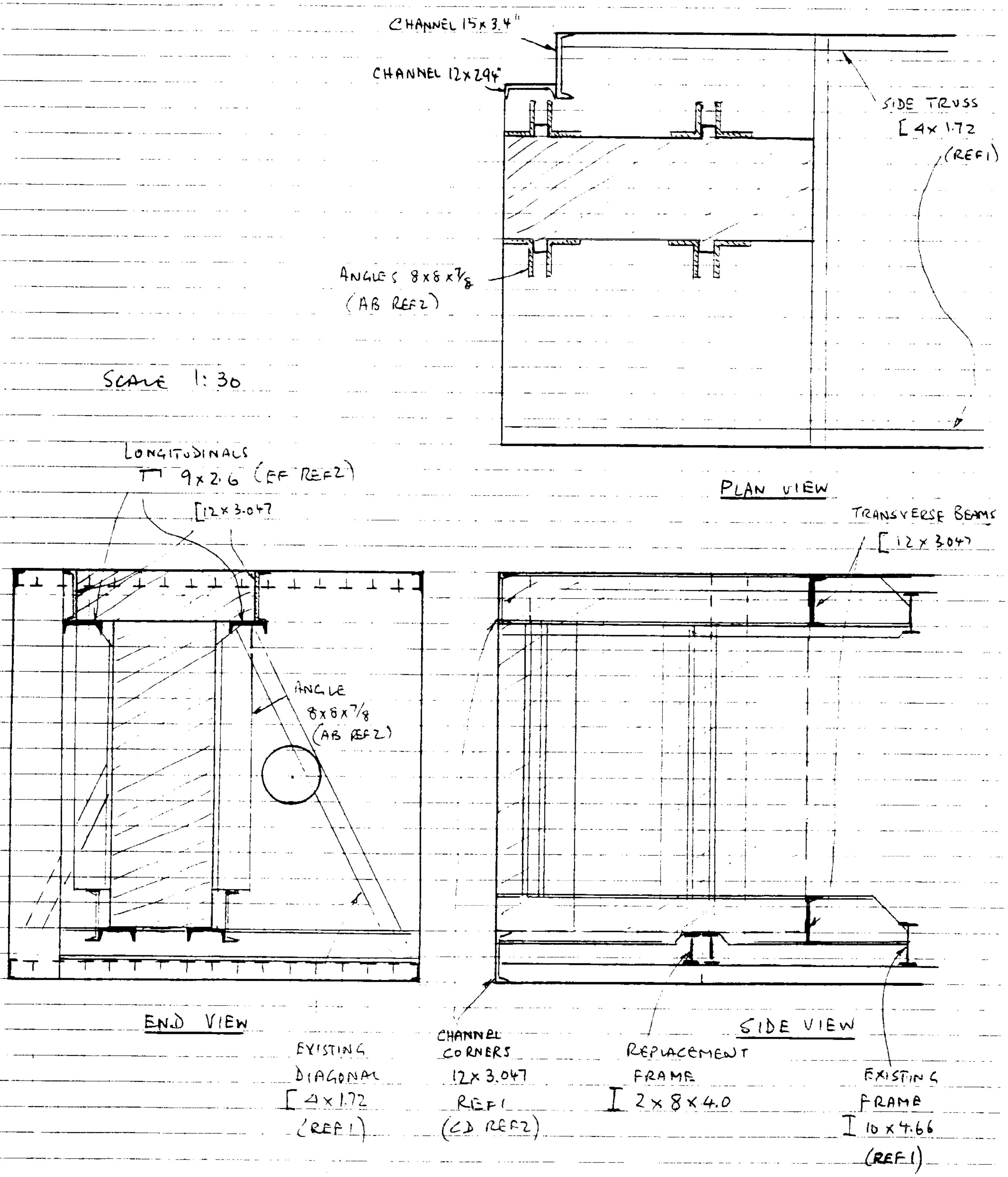


NOTE:
- 1/4" SKIN PLATING NOT SHOWN ON DIAGRAM. LOCK-IN BAR MUST BE REPLACED WHEN NAVY CONNECTOR IS REMOVED.
- LIGHTER MUST BE WATERTIGHT WHETHER OR NOT NAVY CONNECTOR IS INSTALLED.

2. END CONNECTORS



2.1 END CONNECTOR SUPPORT SYSTEM



3. ADDED WEIGHT OF CONNECTOR SUPPORT SYSTEMS.

3.1 SIDE CONNECTOR

			LENGTH	WT/FT	No.	WT./CONNECTOR
ADDED	SLIDE ANGLES	L 8x8x7/8	5.5	45 lb	8	1980 LB
	FRAMES	[12x3.047	8	25 lb	4	800
	CROSS BEAMS	[9x2.648	8	20 lb	4	640 LB
	LOCK IN BARS	L 4x4x	6	12.8	2	154
	PLATE	1/4"	110 sq.ft	10.2 lb/sq.ft	1	1122
					+	4696 LB
SUBTRACTED						
	FRAMES	I 10x4.66	8	25.4	2	486
	STIFFENERS	⊥ 4x2.7	2	6.84	12	164
	TRUSS MEMBERS	[4x2.7	12	6.84	2	164
	PLATING	1/4"	26 sq ft	10.2 lb/sq ft		265
					−	1079

NET WT. INCREASE + 3617 LB

(WEIGHT INCREASE IS FOR ONE SIDE CONNECTOR, DOES NOT INCLUDE WEIGHT OF CONNECTOR NOR WEIGHT PENALTY DUE TO ALIGNMENT SYSTEM)

3.2 END CONNECTOR

			LENGTH	WT/FT	No	WT/CONNECTOR
ADDED	SLIDE ANGLES	L 8 x 8 x 7/8	5.5	45	8	1980 LB
	TRANSVERSE BEAMS	[12 x 3.047	8	25	2	400
	LONGITUDINALS	[12 x 3.047	8	25	4	800
	"	[9 x 2.648	8	20	4	640
	FRAME	I 8 x 4.0	8	18.4	2	294
	PLATING	1/4"	110 sq ft	10.2 lb/sq ft	1	1122
	LOCK IN BARS	L 4 x 4 ?	6	12.8	2	154
					+	5390

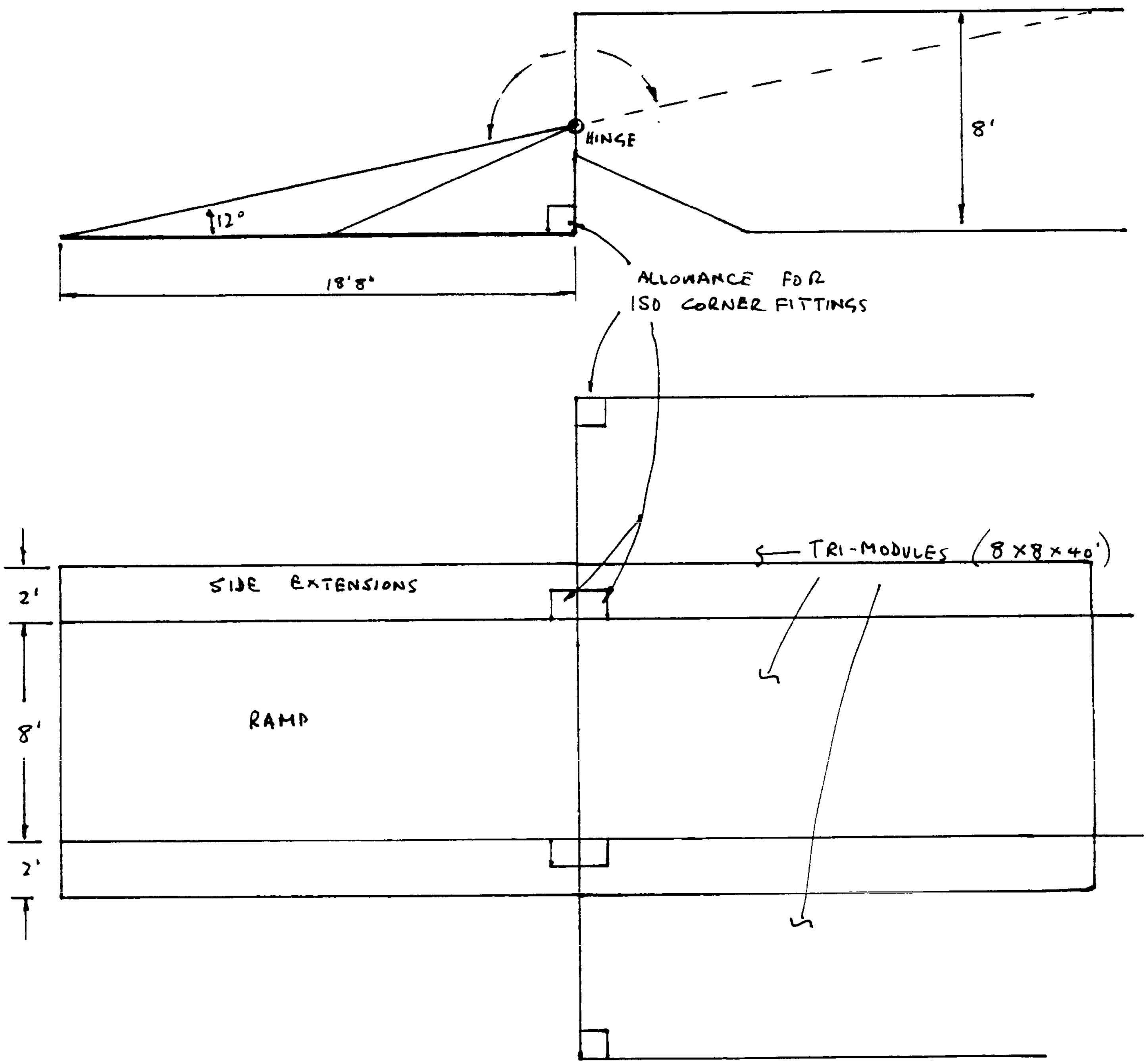
SUBTRACTED						
	FRAME	I 10 x 4.66	10	25.4	1	254
	STIFFENERS	⊥ 4 x 2.7	6	6.84	5	205
	TRUSS MEMBERS	[4 x 2.7	10	6.84	2	137
	PLATING	1/4"	26 sq ft	10.2 lb/sq ft		265
					−	861

NET WT. INCREASE: 4529 lb

(WEIGHT INCREASE FOR ONE END CONNECTOR, DOES NOT INCLUDE WT OF CONNECTOR NOR WEIGHT PENALTY DUE TO ALIGNMENT PIN SYSTEM.

1. STRUCTURAL DESIGN OF ACB LIGHTER RAMP ①

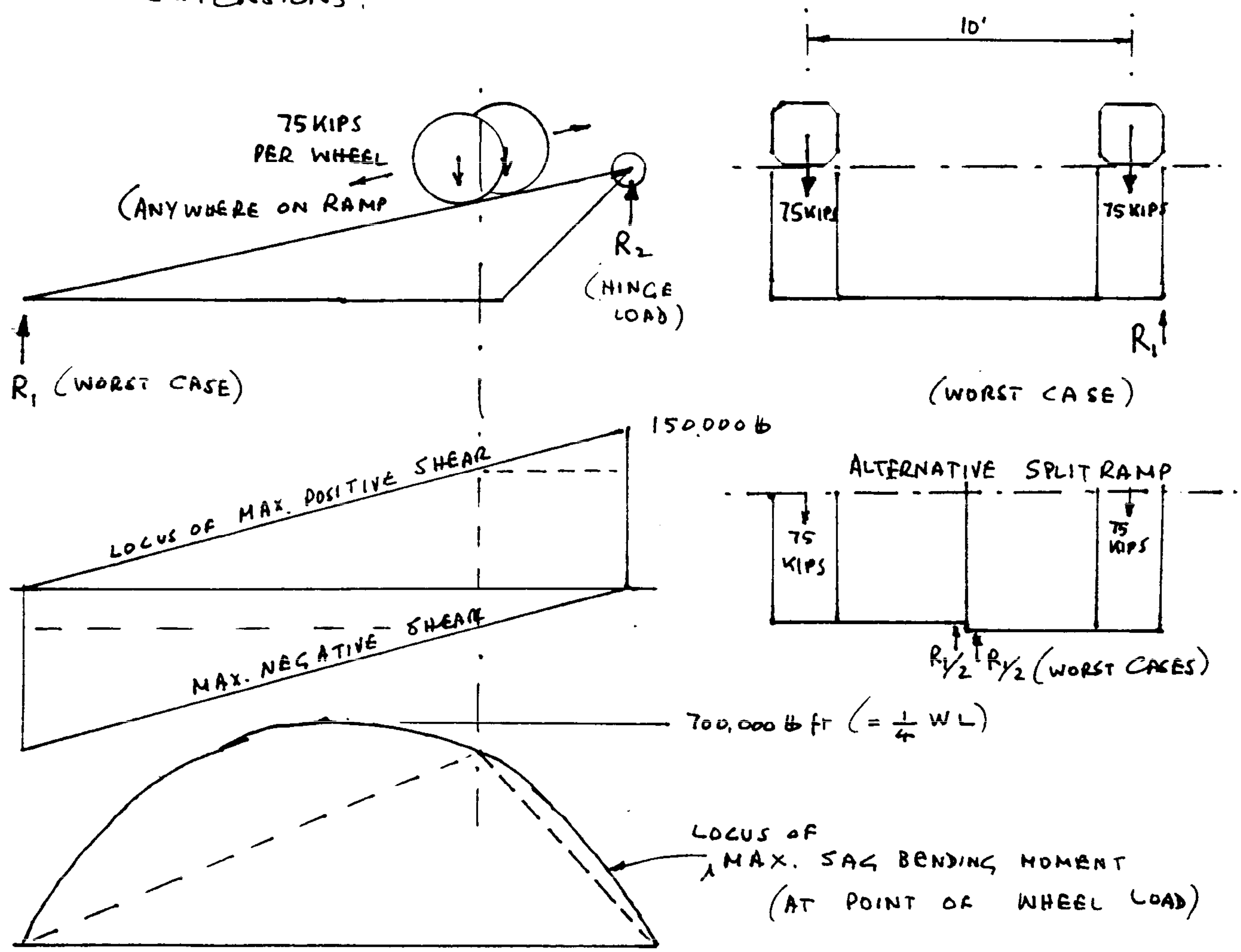
1.1. SCHEMATIC OF RAMP



1.2. LOADS

THE DESIGN LOAD FOR THE DECK OF THE ACB LIGHTER IS THE WHEEL LOAD OF THE ROUGH TERRAIN CONTAINER HANDLER (RTCH). THIS LOAD IS 75,000# ON EACH OF TWO WHEELS SPACED 10 FT APART. EACH 75,000# LOAD IS DISTRIBUTED OVER A 2 x 2 FT SQUARE AREA. (REF 1)

THIS LOAD WILL ALSO BE ASSUMED TO BE THE DESIGN LOAD FOR THE RAMP AND RAMP SIDE EXTENSIONS.



REF 1 MJP&A REPORT # 95-012 (15 JULY 1995)

③

1.3. RAMP DECK & STIFFENERS.

RAMP DECK SHOULD BE CONSTRUCTED IN SAME WAY AS LIGHTER DECK (SEE REF. 2) i.e.

DECK 1/4" STEEL PLATE (10.2 lb/sq. ft)

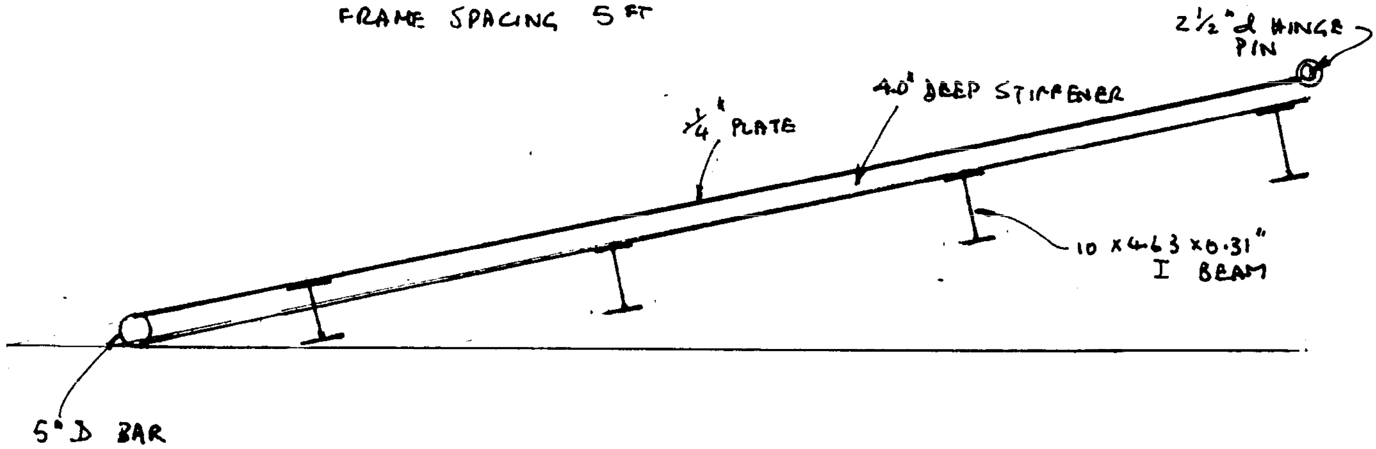
STIFFENERS ⊥ 4.0 x 0.25 x 2.7 x 0.355" (6.84 lb/ft)

STIFFENER SPACING 6"

1.4. RAMP FRAMES (4FT SPAN) (REF 2 SECTION A 3.3.3)

FRAME BEAM I 10 x 4.63 x 0.31" (25.4 lb/ft)

FRAME SPACING 5 FT



1.5. RAMP HINGE

WORST LOAD ON ONE HINGE PIN ≈ 75 KIPS

ASSUMING 20,000 psi ALLOWABLE SHEAR STRESS

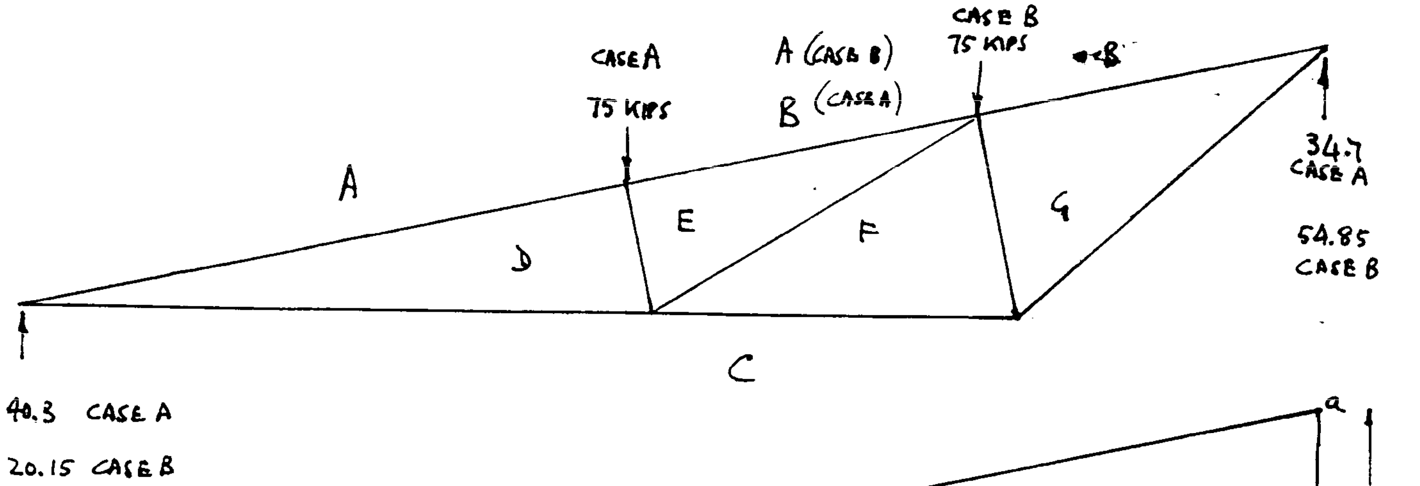
ALLOWABLE LOAD ON 2½"D PIN IS 98,000 lb

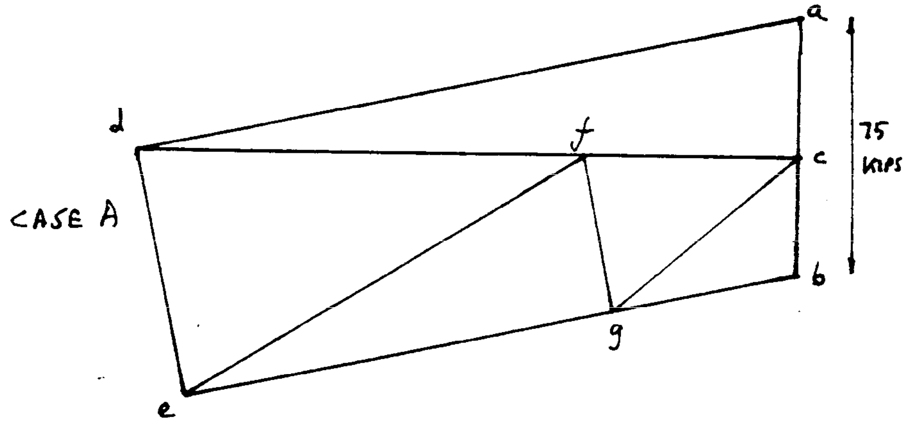
∴ USE 2½"D HINGE PINS FOR RAMP

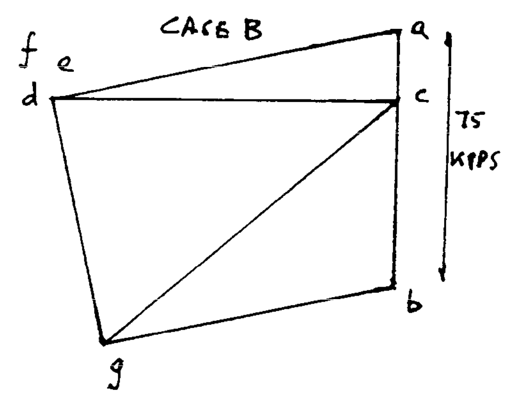
REF 2 ACB LIGHTER TRIMODULE DESIGN. NOTE BY E. BAND TO MJP&A SEPT 28, 1995

1.6. RAMP SIDE TRUSS

④







MEMBER	LOADS (KIPS) CASE A	CASE B	LENGTH (IN)
AD	195 C	100 C	105
DC	190 T	100 T	108
DE	73 C	0	24
AE/BE	180 C	75 C	60
EF	130 T	0	65
FC	62 T	100 T	62
FG	45 C	73 C	36
BG	55 C	85 C	60
CG	70 T	110 T	72

CHECK AD FOR CRITICAL COLUMN LOAD

$$P_c = 4\pi^2 EI/L^2 \quad (E = 3\times10^7)$$
$$= 107\ I \quad (L_{AD} = 105")$$

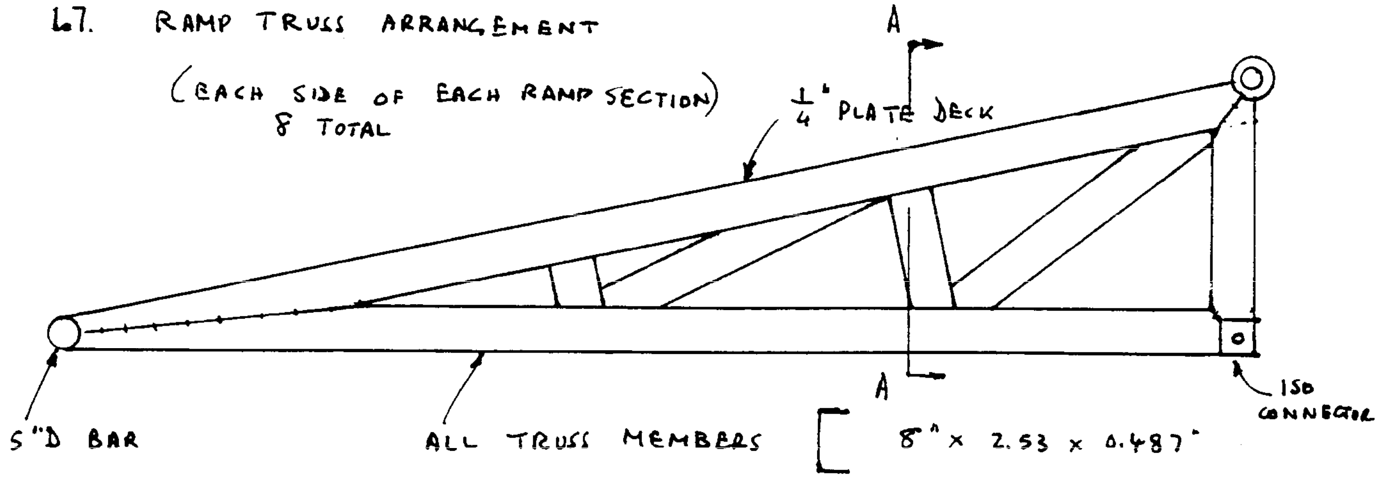
THUS $I_{\substack{MIN\\AD}} = 195/107 = 1.82\ in^4$

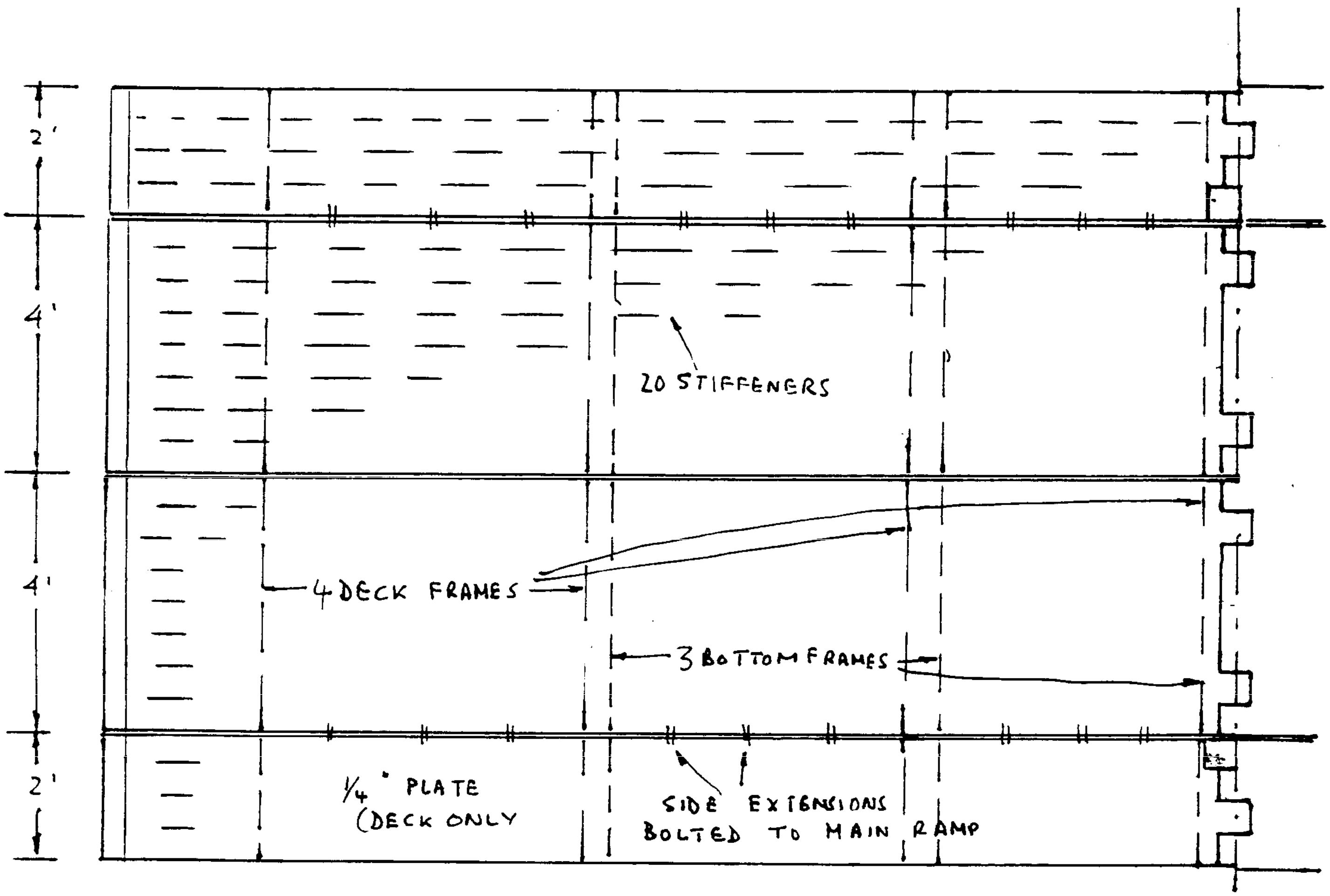
USE CHANNEL $8 \times 2.53 \times .487"$ $\quad A = 5.49\ in^2,\ r = 0.6" \ \} \ I = 1.98\ in^4$

5

1.7. RAMP TRUSS ARRANGEMENT

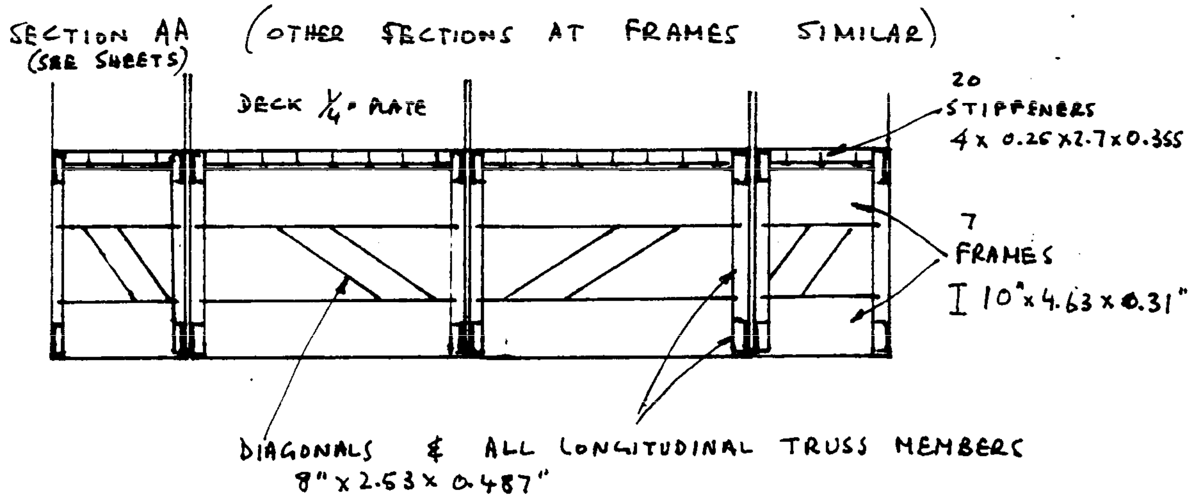
(EACH SIDE OF EACH RAMP SECTION)
8 TOTAL





6

1.8 TRANSVERSE FRAMING



1.9 WEIGHTS (RAMP AND TWO SIDE EXTENSIONS)

ITEM	TYPE	DIMENSIONS	UNIT WT.	SIZE	NUMBER	WEIGHT (LB)
DECK	PLATE	1/4"	10.2 lb/sq. ft	17.25' x 12'	1	2111
STIFF'N'R	⊥	4 x 1/4 + 2.7 x 3/8"	6.84 lb/ft	17.25'	20	2360
FRAME BEAM	I	10 x 4.66 x 0.31"	25.4 lb/ft	12.0'	7	2134
SIDE TRUSS	[	8 x 2.53 x 0.487"	18.75 lb/ft	46.25' (7 pieces)	8	6938
TRANSVERSE DIAGONALS	[	8 x 2.53 x 0.487"	18.75 lb/ft	6.75' (4 pieces)	3	380
BAR AT TIP	⊘	5" D	67 lb/ft	12'	1	804
HINGE	◎	5" OD 2½" ID	50.25 lb/ft	.5'	6	151
						14878 LB

WEIGHT OF 8 FT WIDE CENTER RAMP 8799

WEIGHT OF 4 FT WIDE SIDE EXTENSION 3039.5

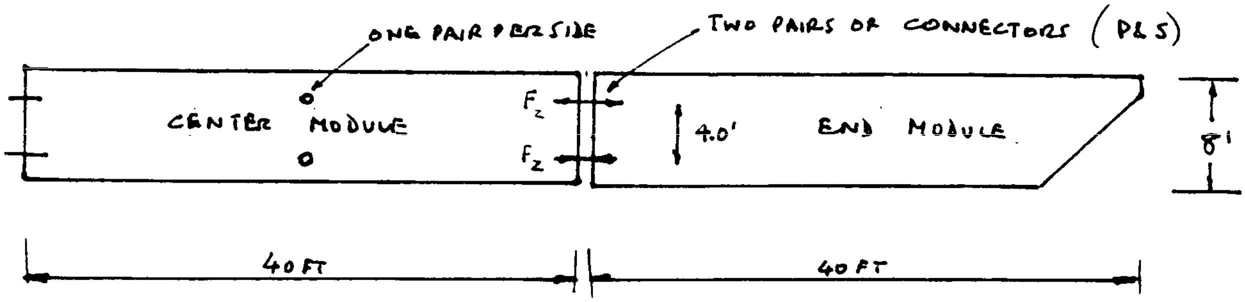
3039.5

14878 LB

7

2. CONNECTOR LOADS (NAVY DESIGN CONNECTORS)

2.1. END CONNECTIONS



"WORST CASE" LOAD IS
FROM REF.3 "SURVIVAL" BENDING MOMENT AT CONNECTORS
(FOR TWO MODULES EACH 40' x 24' x 8')

$$BM = 21.4 \times 10^5 \text{ lb ft} \quad (\text{TWICE SIG. VALUE SS 5},\ H_{sig} = 10')$$

THUS LOAD IN CONNECTORS IS GIVEN BY:

$$2 \times F_z \times 4 = 21.4 \times 10^5$$

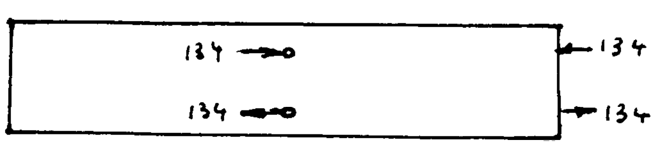
$$F_z = 2.675 \times 10^5 \text{ lb}$$
$$= 267.5 \text{ KIPS}$$

2.2. SIDE CONNECTIONS

REF 3 DOES NOT ADDRESS SIDE CONNECTOR LOADS.

ASSUME THAT DIFFERENTIAL PITCHING BETWEEN SIDE CONNECTED MODULES WILL BE LESS THAN (SAY ½) END-TO-END BENDING MOMENT.

THUS "WORST CASE" LOAD COMBINATION COULD BE:

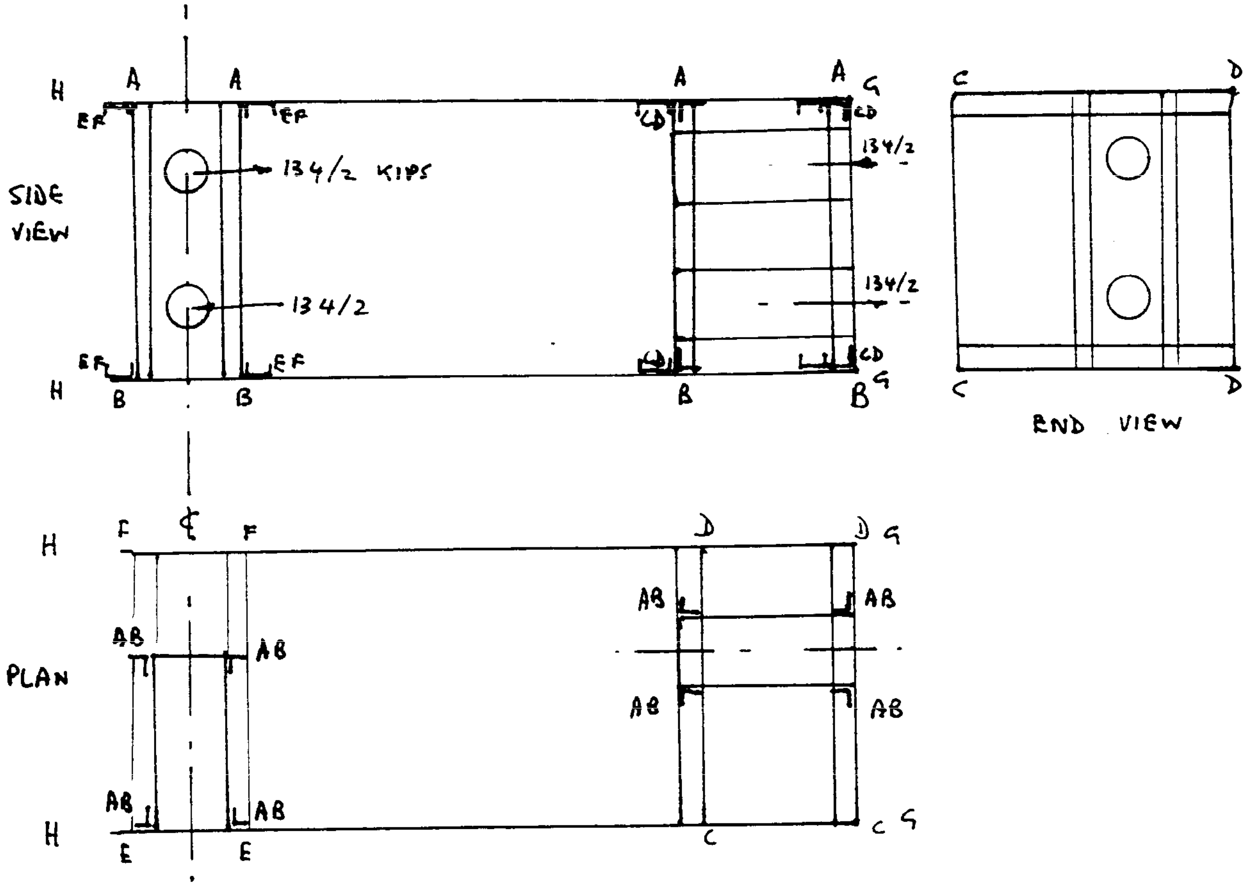


} EACH SIDE OF CENTER MODULE

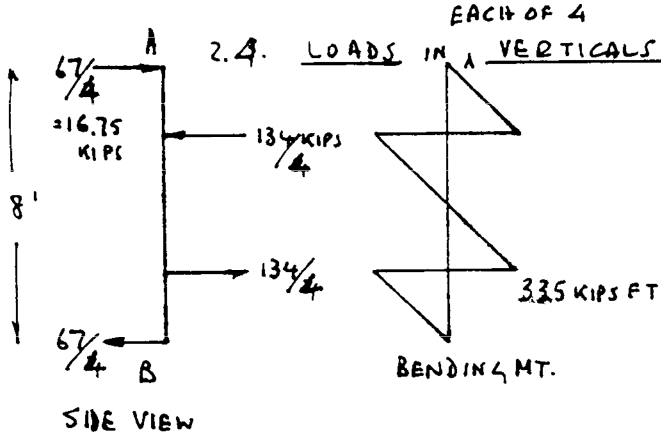
REF 3 "OCEAN MODULE BARGE CONNECTION SYSTEM DEVELOPMENT VOL 2"
C.J. GARRISON & ASSOC. REPORT # 110-93 SEPT. 1993

8

2.3. PROPOSED STRUCTURE



2.4. LOADS IN EACH OF 4 VERTICALS AB



MAX. STRESS $f = 30{,}000$ psi

$= M/Z$

$\therefore Z = M/f$

$= 33500 \times 12 / 30.000$

$= 13.4 \text{ in}^3$

USE L $8 \times 8 \times 7/8$" $Z = 14 \text{ in}^3$

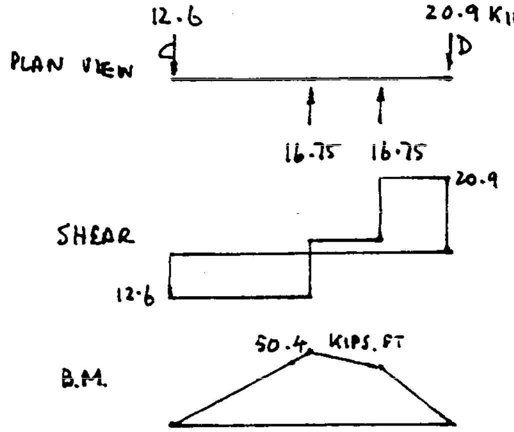
$W = 45$ lb/ft

WEIGHT PER MODULE $= 45 \times 8 \times 12$

$= 4320$ lb

9

2.5 LOADS IN CROSS BEAMS CD:



$Z = M/f$

$= 50{,}400 \times 12 / 30{,}000$

$= 20.16 \text{ in}^3$

USE ⌶ $10 \times 3.033 \times 0.673$

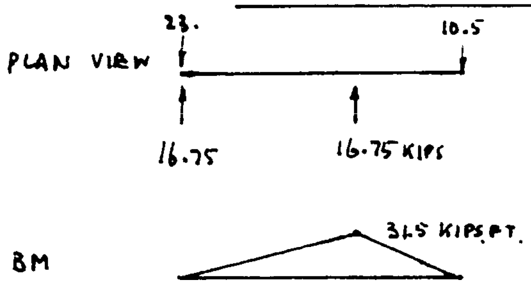
$S_{xx} = 20.6 \text{ in}^3$

$W = 30 \text{ lb/ft}$

WEIGHT PER MODULE $= 30 \times 8 \times 8$

$= 1920 \text{ lb}$

2.6 LOADS IN CROSS BEAMS EF:



$Z = M/f$

$= 31{,}500 \times 12 / 30{,}000$

$= 12.6 \text{ in}^3$

USE ⌶ $9 \times 2.648 \times 0.448$

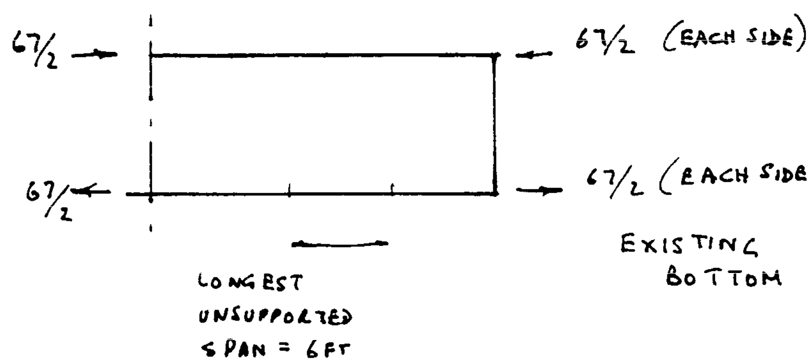
$S_{xx} = 13.5 \text{ in}^3$

$W = 20 \text{ lb/ft}$

WEIGHT PER MODULE $= 20 \times 8 \times 4$

$= 640 \text{ lb}$

2.7 LOADS IN LONGITUDINALS GH:



CRITICAL COLUMN LOAD

$P_c = 4\pi^2 EI/L^2 \quad (E = 3\times10^7)$

$= 228.5\, I \text{ kips} \quad L = 72''$

$\therefore I = 33.5/228.5$

$= 0.146 \text{ in}^4$

EXISTING LONGITUDINALS AT TOP AND BOTTOM CORNERS ARE: ⌊ $4 \times 1.72 \times 0.32$

$I = 0.45 \text{ in}^4$

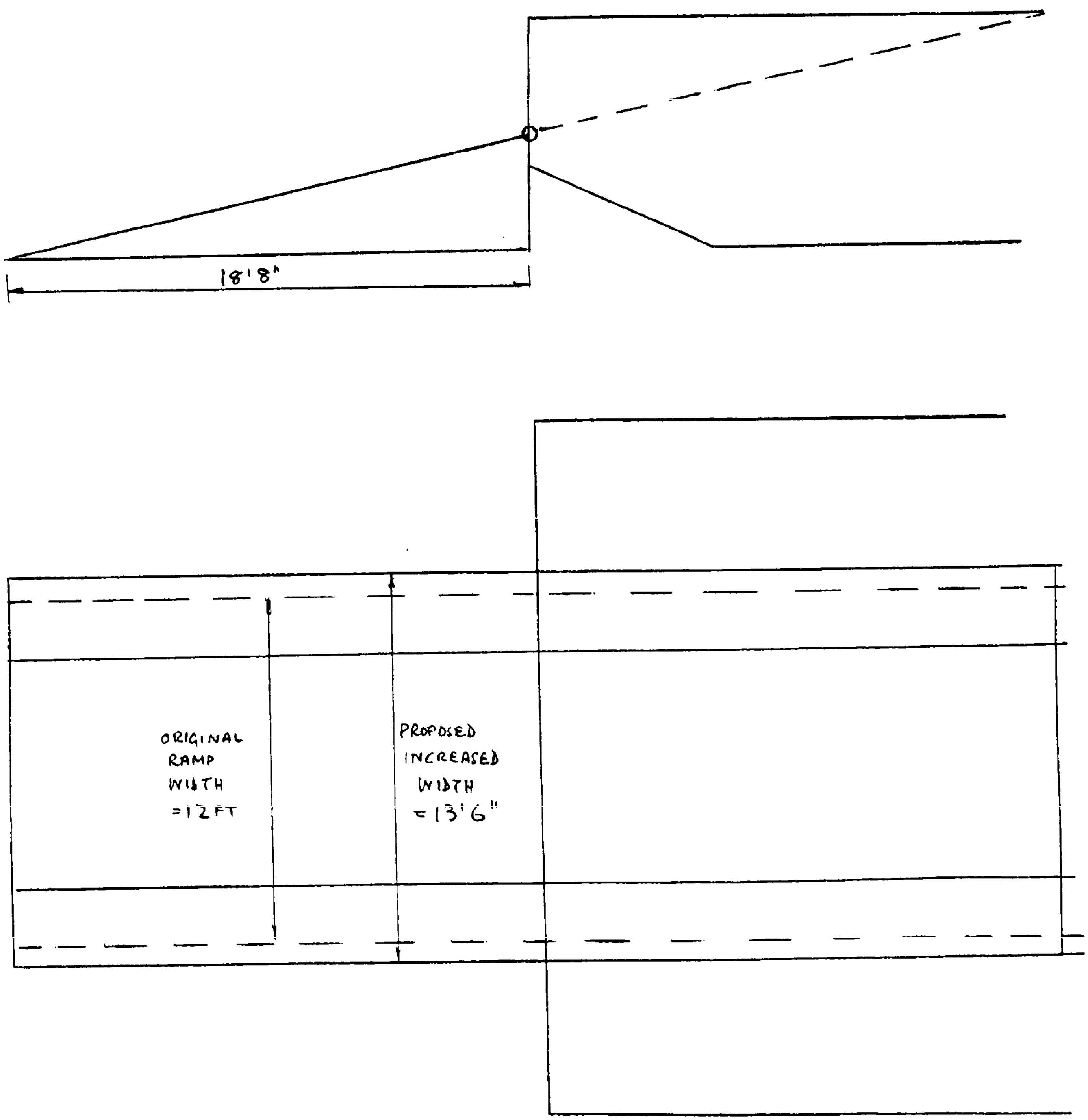
THEREFORE EXISTING STRUCTURE CAN SUPPORT LOADS IN LONGITUDINALS GH.

2.8 WEIGHT PENALTY TO TRANSFER CONNECTOR LOADS TO STRUCTURE

12 VERTICAL ANGLES AB 8 FT. LONG EACH		
L 8 x 8 x 7/8" (45 LB/FT)		4320 LB
8 CROSS BEAMS CD 8 FT. LONG EACH		
⊓ 10 x 3.033 x 0.673" (30 lb/ft)		1920 LB
4 CROSS BEAMS EF 8 FT LONG EACH		
⊓ 9 x 2.648 x 0.448" (20 lb/ft)		640 LB
4 LONGITUDINALS	NO EXTRA STRUCTURE	0
	TOTAL	6880 LB

NOTE: THIS WEIGHT DOES <u>NOT</u> INCLUDE THE WEIGHT OF THE CONNECTORS THEMSELVES.

WIDENING OF ACB LIGHTER RAMP



WIDENING OF ACB LIGHTER RAMP (CONT.)

TO BETTER ACCOMODATE U.S. ARMY VEHICLES IT HAS BEEN FOUND NECESSARY TO INCREASE RAMP WIDTH BY 9" EACH SIDE. THUS EACH SIDE PIECE OF THE RAMP WILL BE INCREASED IN WIDTH FROM 2FT TO 2FT 9IN.

A BRIEF REVIEW OF THE STRUCTURAL ANALYSIS OF THE ORIGINALLY PROPOSED STRUCTURE (MEMO FROM EG.U.B TO MJP&A, MARCH 27 1996) SHOWS THAT THIS INCREASED WIDTH WILL CAUSE NO ADDITIONAL STRUCTURAL PROBLEMS.

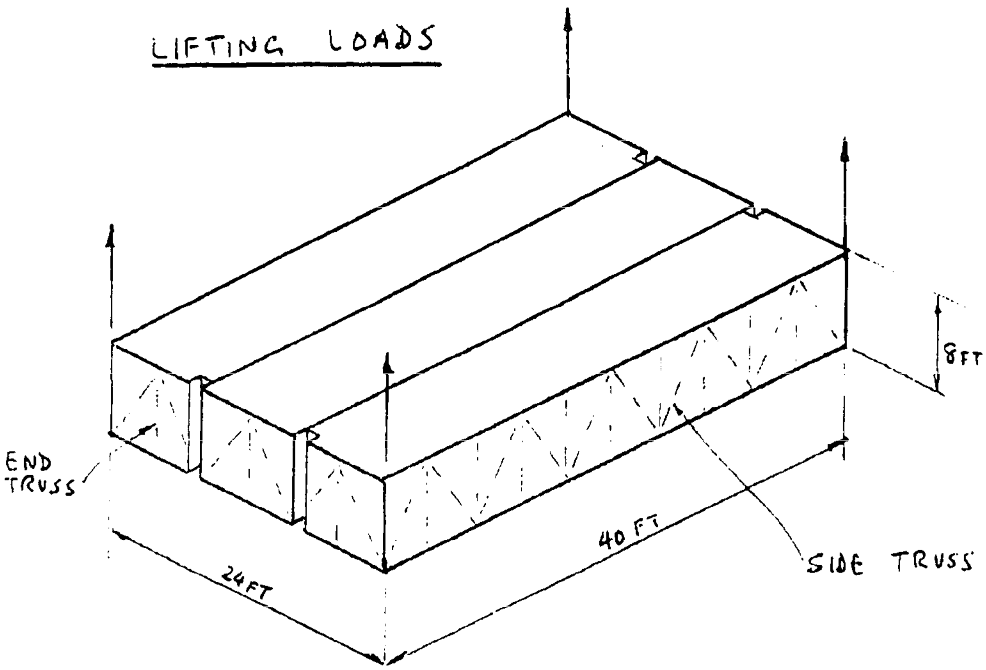
WEIGHT INCREASE OF RAMP WILL BE AS FOLLOWS:

			ADD'L	LB
DECK PLATING	1/4"	10.2 LB/SQ.FT	17.25 x 1.5	264
FRAME BEAMS		25.4 LB/FT	1.5 FT x 7	267
TRANS. DIAGONALS		18.75 LB/FT	1.5 x 3	84
BAR AT RAMP TIP		50.25 LB/FT	1.5	75

TOTAL INCREASE IN WEIGHT 690 LB

ACB LIGHTER

LIFTING LOADS



1. ASSUMPTIONS:

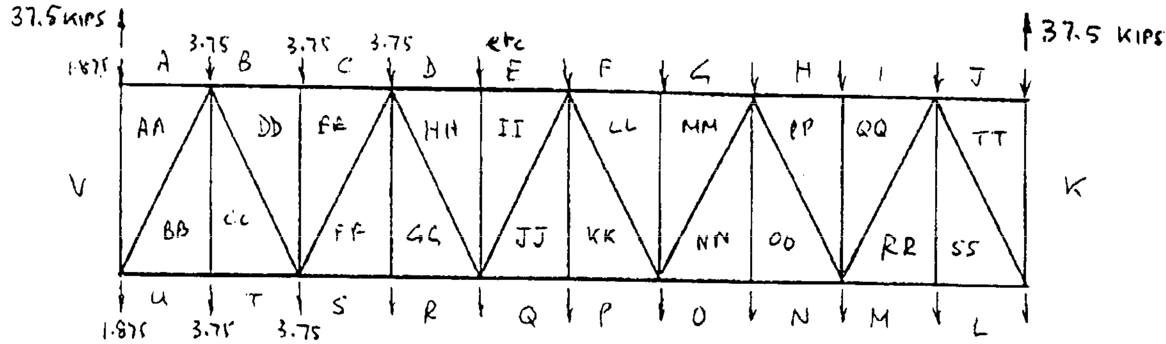
1. WEIGHT OF TRIMODULE IN LIFT CONDITION = 50 TONS
= 112,000 LB
ASSUME DESIGN LOAD = 150,000 LB

2. MOST SEVERE CASE FOR 4 LIFT POINTS IS ONE LIFT POINT AT EACH OUTER CORNER AS SKETCHED.
MAX. LOAD AT EACH CORNER ≅ 37,500 LB

3. ASSUME 1/2 LONGITUDINAL BENDING MT. TAKEN IN EACH OUTER SIDE TRUSS

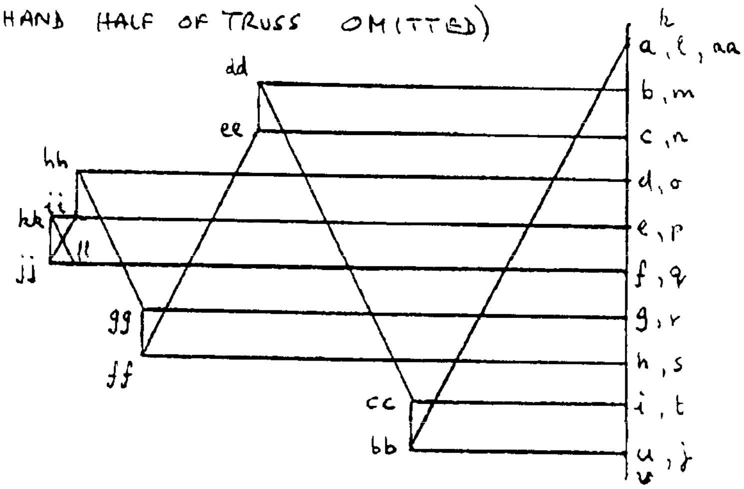
4. ASSUME 1/2 TRANSVERSE BENDING MT. TAKEN IN EACH END TRUSS

7. SIDE TRUSS LOADS



LOAD DIAGRAM (1" = 15 KIPS)

(LOADS IN RIGHT-HAND HALF OF TRUSS OMITTED)



3. LOADS TABLE:

MEMBER	LOAD (KIPS)	TENS/COMP	
A AA, J TT	0	–	UPPER LONGITUDINALS $L = 4$ ft
B DD, I QQ	30	C	
C EE, H PP	30	C	
D HH, G MM	45	C	
E II, F LL	4	C	
BB U, SS L	16.9	T	LOWER LONGITUDINALS $L = 4$ ft
CC T, RR M	16.9	T	
FF S, OO N	39.4	T	
GG R, NN O	39.4	T	
JJ Q, KK P	46.9	T	
AA BB, SS TT	37.5	C	DIAGONALS $L = 8$ ft
CC DD, RR QQ	30	T	
EE FF, PP OO	21	C	
GG HH, NN MM	12	T	
II JJ, LL KK	4.5	C	
V AA, K TT	35.6	T	VERTICALS $L = 7.2$ ft
BB CC, RR SS	3.75	T	
DD EE, PP QQ	3.75	C	
FF GG, NN OO	3.75	T	
HH II, LL MM	3.75	C	
JJ KK	3.75	T	

4. STRESSES IN TRUSS MEMBERS

ALL LONGITUDINAL TRUSS MEMBERS ARE CONSTRUCTED OF [$4 \times 1.72 \times 0.32$ CHANNEL

$A = 2.12 \text{ in}^2$

$I_{YY} = 0.45 \text{ in}^4$

MAX. TENSILE STRESS (JJQ, KKP) $= 46.9 / 2.12$

$= 22{,}123$ psi ✓

CRITICAL COLUMN LOADS:

$$P_c = n \pi^2 E I / L^2$$

USE $n = 4$ (FIXED ENDS)

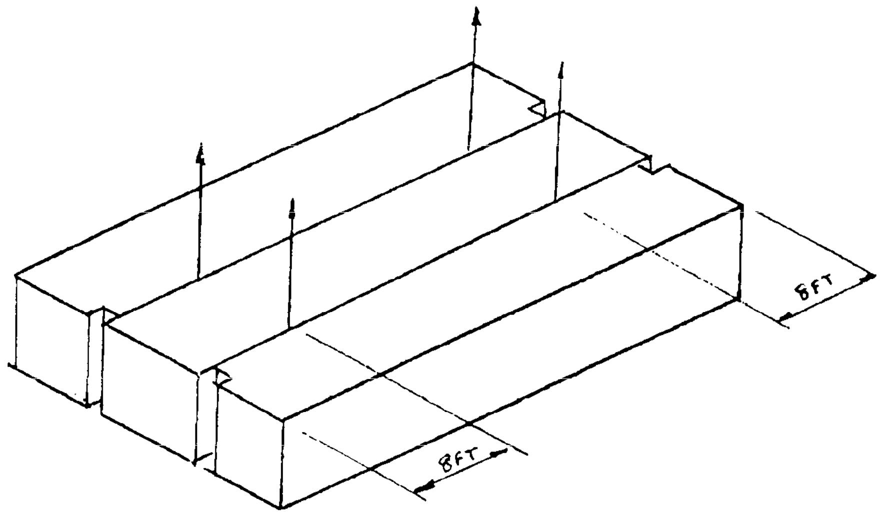
$E = 30 \times 10^6$ psi

MEMBER	L	LOAD (KIPS)	P_c (KIPS)	FACTOR OF SAFETY
LONGITUDINAL DHH, GMM	48"	45	231.3	5.1
DIAGONAL AABB, SSTT	96"	37.5	57.8	1.5
VERTICAL DBEE, PPQQ	86"	3.75	72.1	19

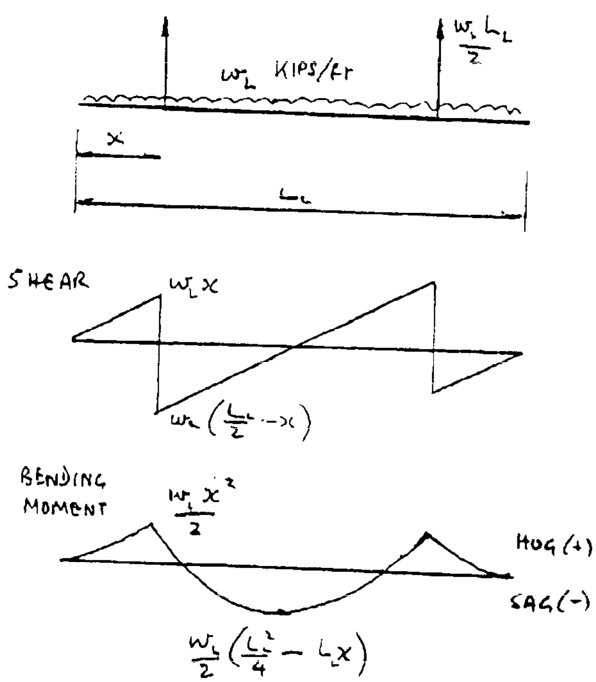
5. END TRUSSES.

END TRUSSES ARE CONSTRUCTED IN THE SAME WAY AS SIDE TRUSSES. AS SPAN (24FT) IS LESS THAN LONGITUDINAL SPAN OF (40FT) END TRUSSES STRESSES WILL BE CORRESPONDINGLY LOWER, AND NEED NOT BE CALCULATED.

6. PREFERRED PICK-UP POINTS.



ALTHOUGH STRESSES INVOLVED BY LIFTING ACB LIGHTER FROM CORNERS (PAGE 1 SKETCH) ARE NOT EXCESSIVE, BENDING MOMENTS AND STRESSES WOULD BE MUCH SMALLER BY LIFTING FROM POINTS 8 FT IN FROM EACH SIDE AND END (SEE SKETCH ABOVE)



FOR ACBL:

$w_L = 75$ KIPS $/40$

$= 1.875$ KIPS/FT (LONG'L)

$w_T = 75/24$

$= 3.125$ KIPS/FT (TRANS.)

$= 1.67\, w_L$

$L_L = 40$ FT

$L_T = 24$ FT

$= 0.6\, L_L$

SEE TABLE OVERLEAF

6. PREFERRED LIFT POINTS (CONT.)

CASE		LIFT AT CORNERS $x_L = x_T = 0$	LIFT AT INBOARD PTS. $x_L = L_L/5$, $x_T = L_T/3$
LONG'L	BM AT LIFT POINT	0	$+w_L L_L^2/50$
	BM AT MID LENGTH	$-w_L L_L^2/8$	$-w_L L_L^2/40$
TRANS.	BM AT LIFT POINT	0	$+w_T L_T^2/18 = +w_L L_L^2/30$
	BM AT MID LENGTH	$-w_T L_T^2/8 = w_L L_L^2/13.33$	$-w_T L_T^2/24 = -w_L L_L^2/40$
WORST CASE BM		$-w_L L_L^2/8$ = 375 KIPS.FT	$+w_L L_L^2/30$ = 102.75 K.FT

7. LIFT FITTINGS

LOAD AT EACH OF 4 FITTINGS = 37.5 KIPS

STRENGTH OF 1" DIAM BOLT:

TENSION (AT 35,000 psi) = 19.28 KIPS
SHEAR (AT 20,000 psi) = 15.7 KIPS

THUS LIFT FITTINGS SECURED BY 4 1"D BOLTS WOULD BE ABLE TO WITHSTAND LIFT LOADS.

8 CONCLUSIONS

1. ACB LIGHTER IS CAPABLE OF RESISTING LIFTING LOADS DEVELOPED BY A FOUR-POINT LIFTING SYSTEM WITHOUT STRENGTHENING EXISTING STRUCTURE.

2. RECOMMENDED LOCATION FOR 4 LIFT POINTS ARE 8 FEET FROM EACH SIDE AND 8 FEET FROM EACH END (SEE SKETCH PAGE 5)

3. ATTACHMENT AT EACH LIFT POINT SHOULD BE DESIGNED TO USE FOUR 1"D BOLTS, OR EQUIVALENT. BOLTS CAN BE USED IN TENSION OR IN SHEAR.

APPENDIX B

PRESENTATION CHARTS

MEETING NFESC - 9 MAY 1996

Amphibious Cargo Beaching Lighter (ACBL) Tri-Module Design & Development Studies

Final Technical Presentation

To

Naval Facilities Engineering Center Port Hueneme, California

9 May 1996

Contract Number N47408-95-C-0201

Prepared by:

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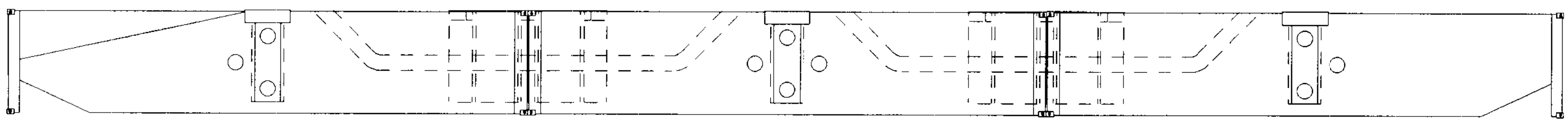
Amphibious Cargo Beaching Lighter (ACBL) Tri-Module Design & Development Studies

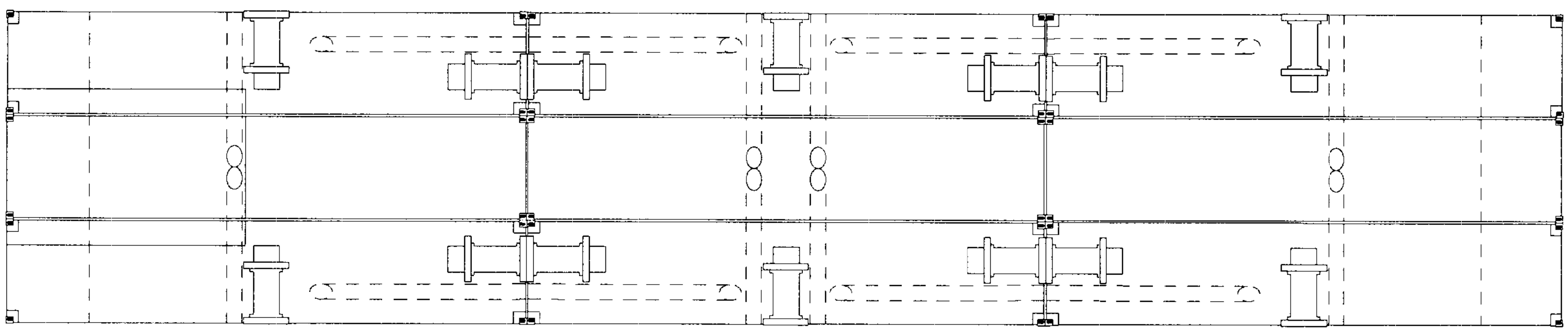
Agenda

- Overview of Studies
- 1/35-Scale Model Design
- Changes to Navy Connectors Necessary for Integration with Tri-Module
- Beach-End Ramp
- NL/MCS Interface Ramp
- Other Details
- Anticipated Problems with Navy Connector System
- Conclusions & Recommendations

Amphibious Cargo Beaching Lighter (ACBL) Tri-Module Design & Development Studies

"As-Built" 1/35-Scale Model





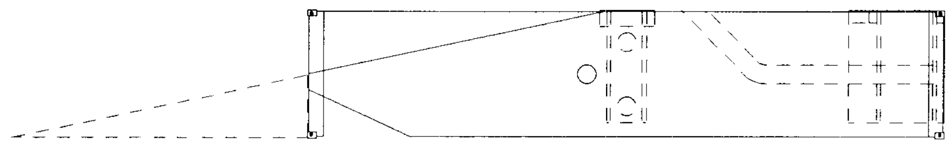
Tri-Modules for Beach-End, Center Section and Rake-End
Positioned as a lighter but with transportation ISO-corners still in place

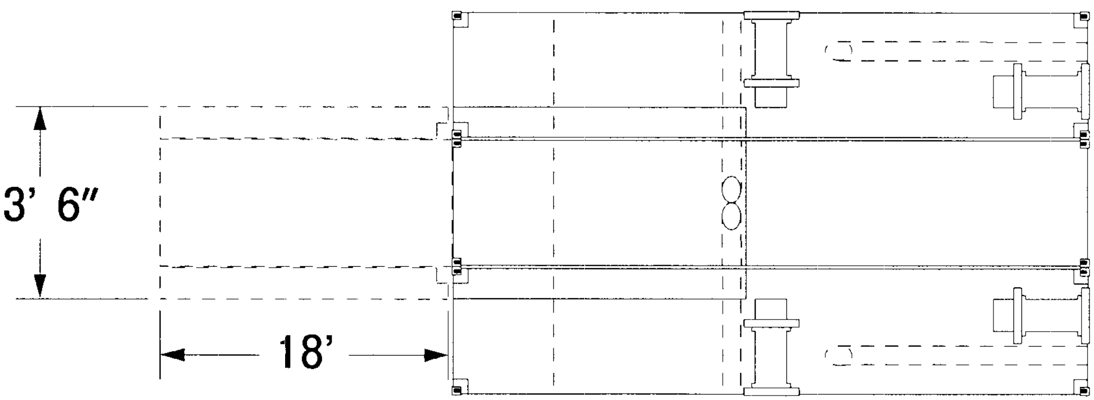
Changes to Navy Connectors Necessary for Integration with Tri-Module

- Alignment Pin Tubes Shortened to Avoid Space Conflict
- Large Flexible Connectors in End Rakes Moved Inboard to Leave Space Free for ISO-Corners
- Rake Angle Reduced from 45° to 25° to Accommodate Beach Ramp

Amphibious Cargo Beaching Lighter (ACBL)
Tri-Module Design & Development Studies

Beach-End Ramp



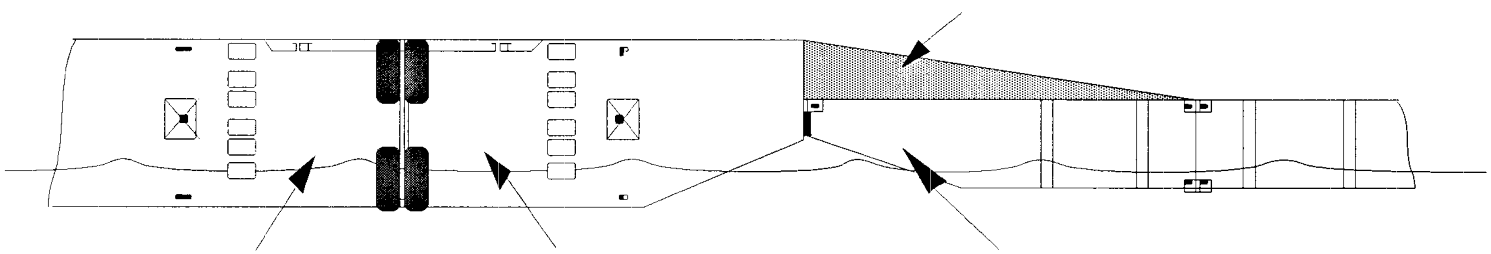


13-ft 6-inch wide Beach-End Ramp is made up by joining a 2-ft 9-inch ramp section hinged to each outer Tri-Module to an 8-foot wide ramp section hinged to the center Tri-Module

Amphibious Cargo Beaching Lighter (ACBL) Tri-Module Design & Development Studies

NL/MCS Interface Ramp Alternatives - 1

3 8-foot wide by 20-foot long Interface Ramps Joined Together

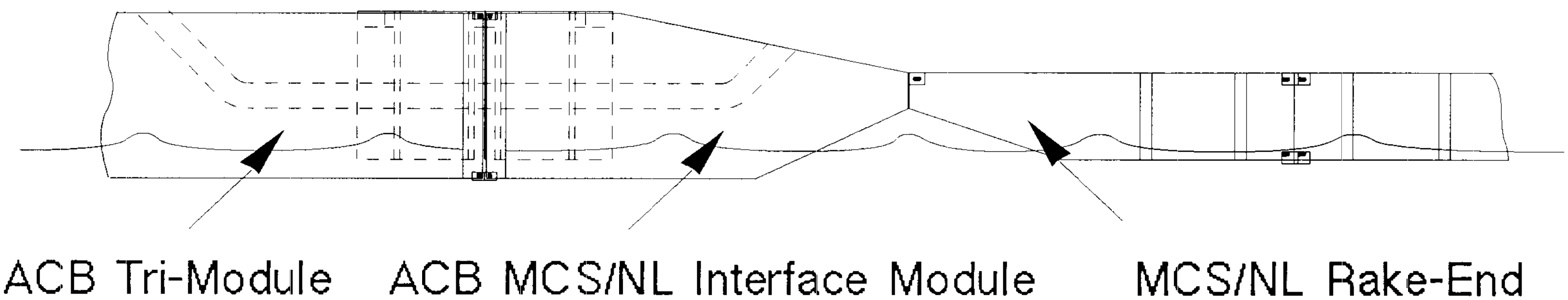


This previously recommended approach requires end-to-end connectors that fit into both the ACB and the MCS/NL that can carry all loads including shear loads at interface.

This approach is not compatible with Navy designed connector system.

Amphibious Cargo Beaching Lighter (ACBL) Tri-Module Design & Development Studies

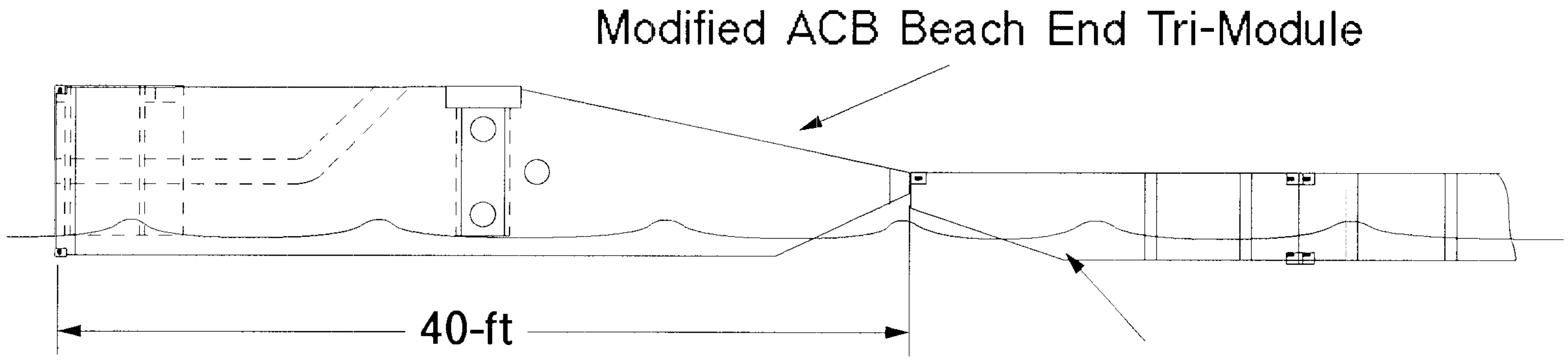
NL/MCS Interface Ramp Alternatives - 2



- This concept requires a special MCS/NL Interface Module with a Navy ACB connector at one end and an NL connector at the other.
- As shown, with a 11.5° sloped deck, two Interface Modules could be stowed nose-to-nose in a 40' space.
- The unit could be used with an existing MCS/NL Beach End as a means of interfacing the ACB with the beach.
- Due to its asymmetry, it would be very difficult to connect even in calm water.

Amphibious Cargo Beaching Lighter (ACBL) Tri-Module Design & Development Studies

NL/MCS Interface Ramp Alternatives - 3



This concept requires a special MCS/NL Interface Tri-Module similar to an ACB Beach End. It would need to be a little shorter to incorporate an MCS/NL connector system in place of its large flexible connectors and stay within ISO length dimensions.

Special ISO corner stacking posts must be designed to interface with the modified end and meet ISO corner dimension requirements.

Potential Problems Integrating Rigid Connector Assembly (RCA) With The Tri-Module Concept

- Just one set of connectors per side does not allow universal positioning of modules, does not allow side-to-side connection of single ACB modules and eliminates the possibility of end-to-side connection.

- Just one set of connectors per 40-foot side leads to very high local loads that are difficult to effectively distribute through the module structure.

- Small (4-foot) vertical separation of rigid connectors leads to higher tension loads to react bending moment than necessary.

- There appears to be no method of adjusting tension in connectors. This requires that modules be aligned exactly before guillotines can be inserted. There will be no ability to compensate for wear or any variation between modules. This may result in either slackness in joint or inability to make the connection.

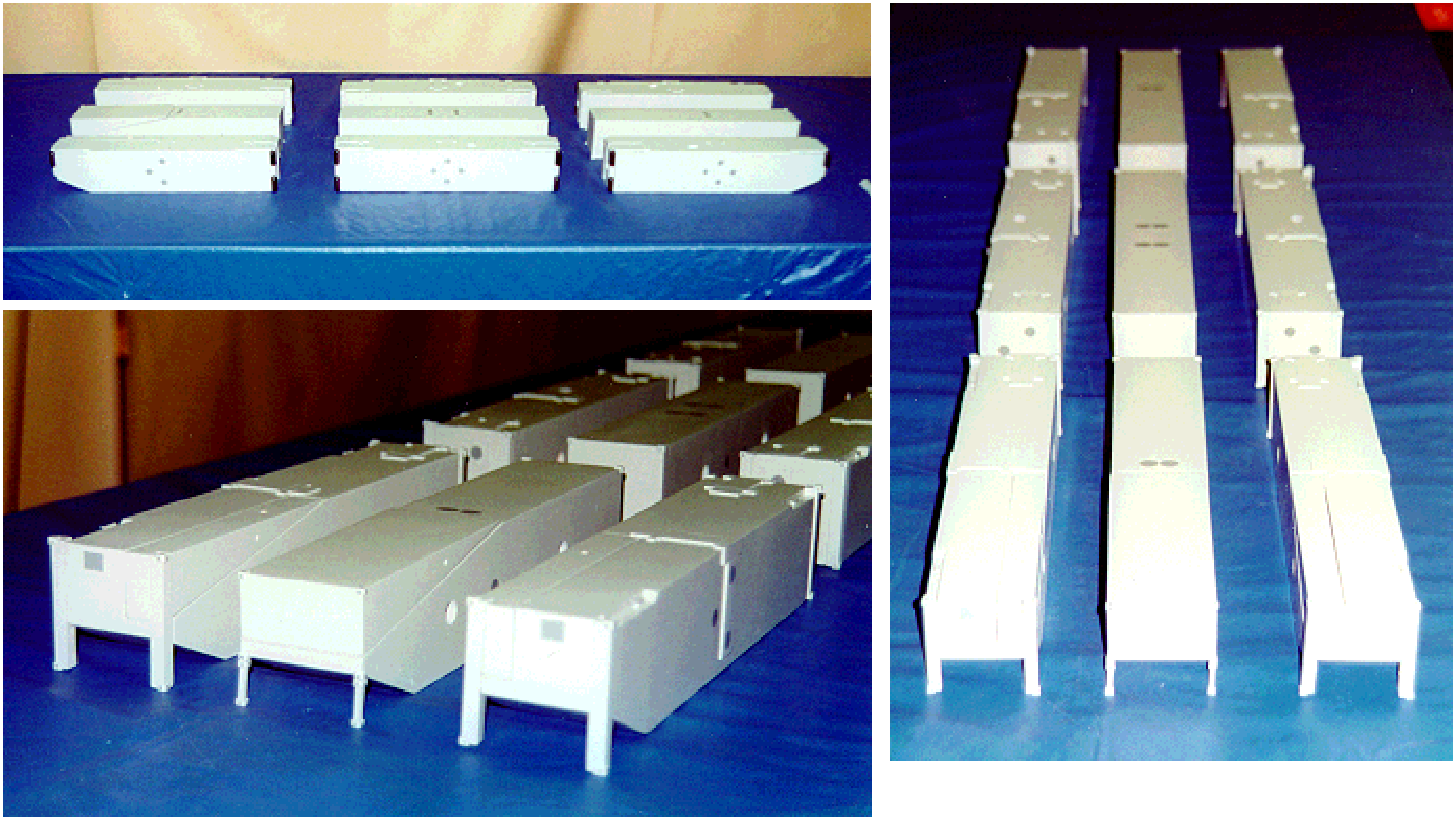
Other Details

- The mooring/towing cleats previously shown on the MJP&A Tri-Module Concept have been incorporated in the model design.
- An additional 1/12-scale model of an ISO-Corner Post and Fender has been made to more clearly illustrate the method of attaching and detaching these key items of the Tri-Module concept.
- One Navy Rigid Connector Module (RCM) has been made removeable from the 1/35th-scale model to illustrate the size of these modules.
- A simplified version of the Large Flexible Connector has also been modeled.

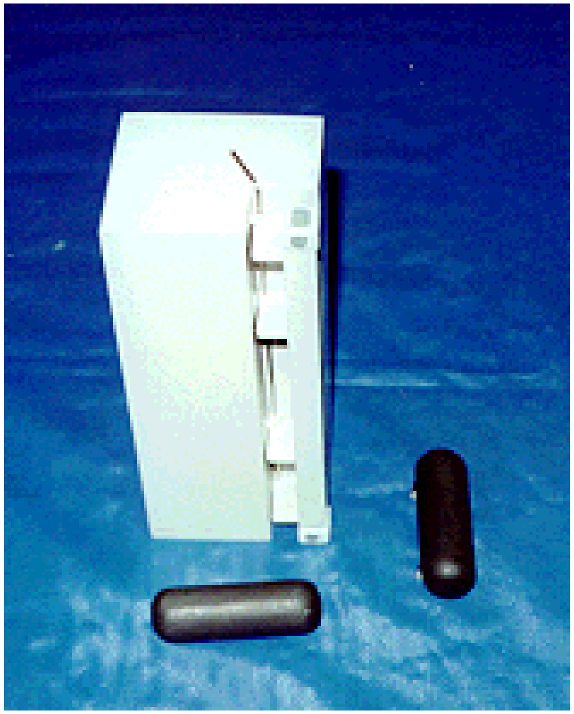
APPENDIX C

PHOTOGRAPHS OF 1/35TH SCALE

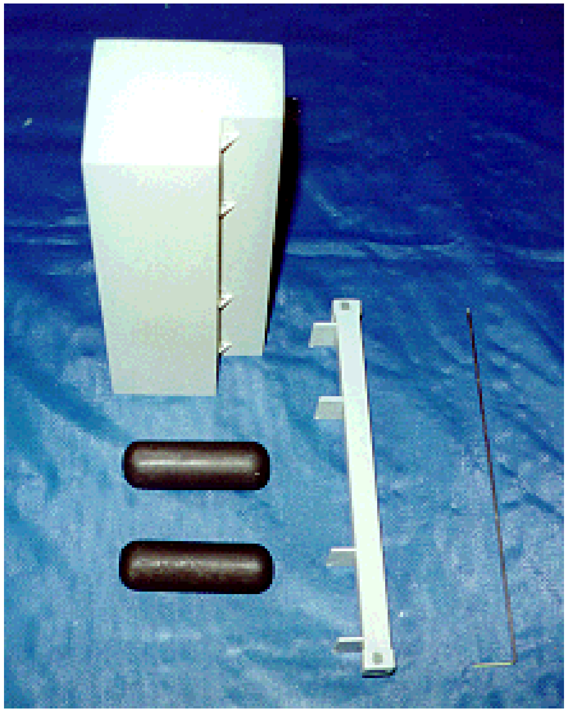
ACBL TRI-MODULE CONCEPT MODEL



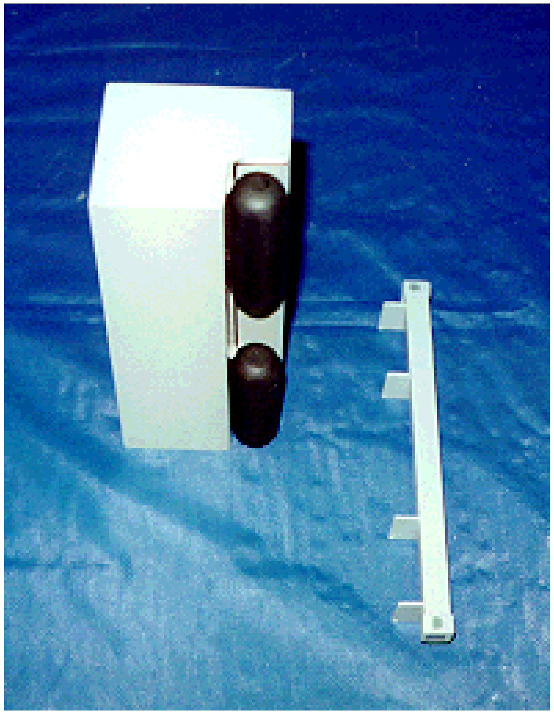
The Amphibious Cargo Beaching Lighter (ACBL) Tri-Modules can be configured into 8- by 8- by 40-ft ISO-compatible units to meet overland transport requirements.



ISO corner post in place for transportation

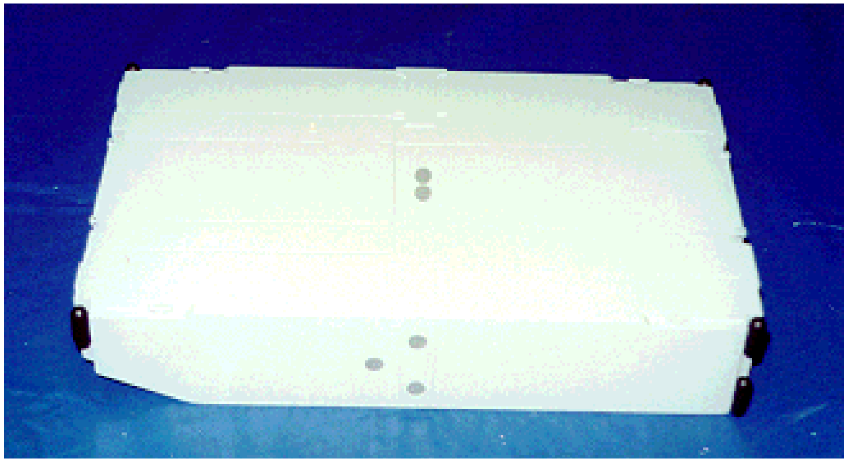


ISO corner post removed

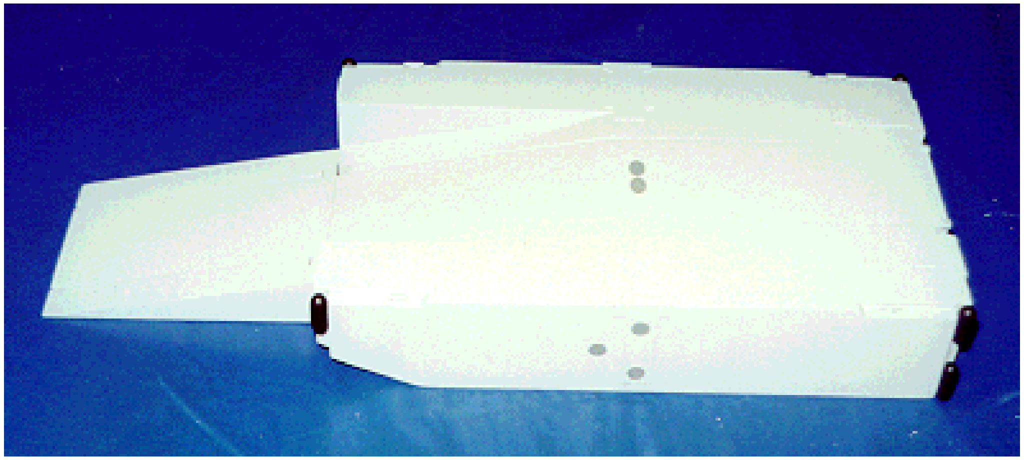


Fenders fitted for operation

Once the Tri-Module units arrive at a port facility, the ISO corner posts are removed from the outboard units. Fenders are then fitted on the far outside corners. Finally, the three intermodal units are side connected into a 24-ft wide by 40-ft long by 8-ft deep ACBL Tri-Module for loading aboard ship.



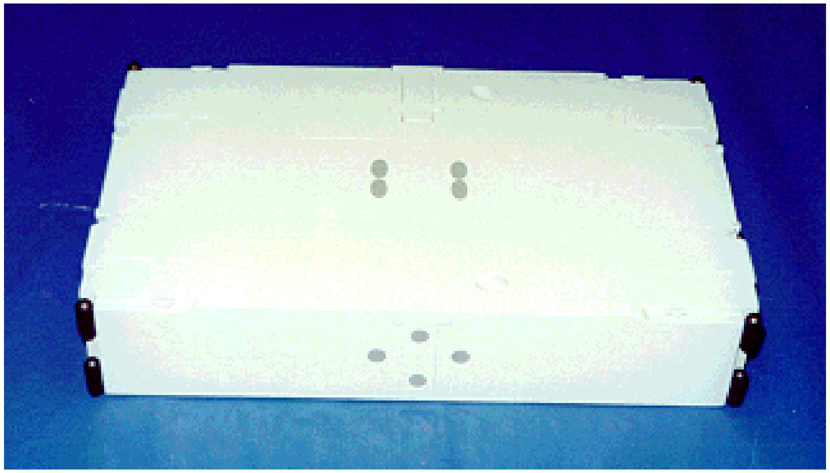
Beach-end ramp module in transport mode



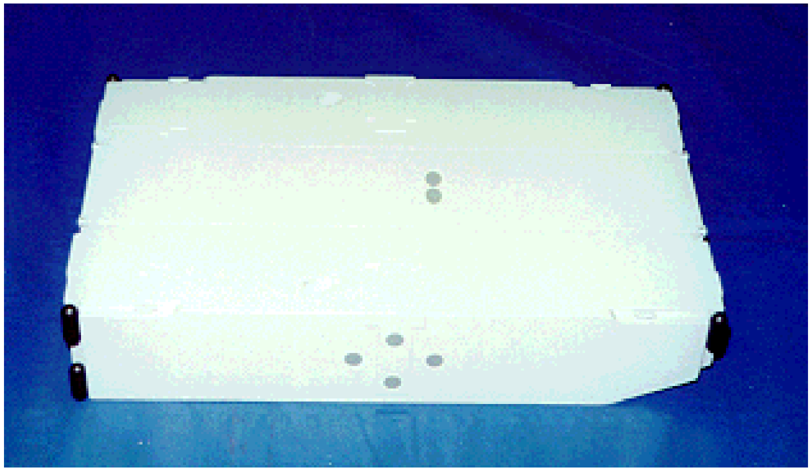
Beach-end ramp module with ramp deployed

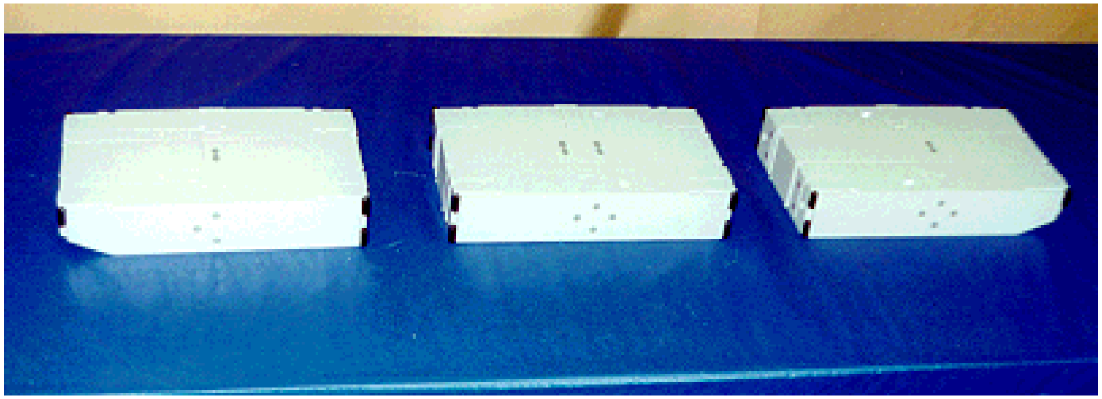
Assembled Tri-Modules

Center module

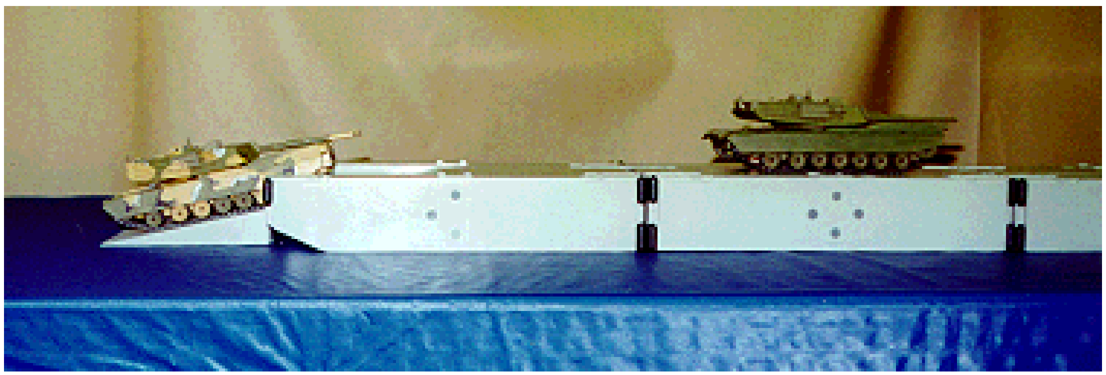


Raked module

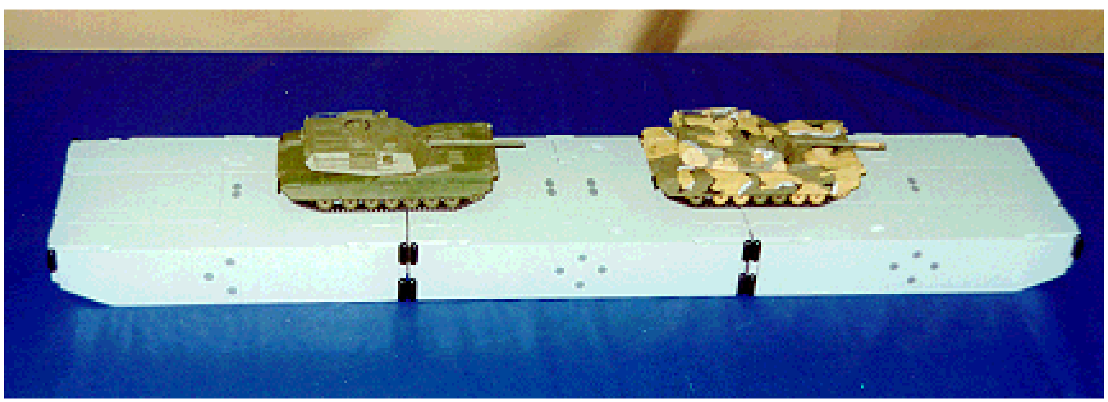




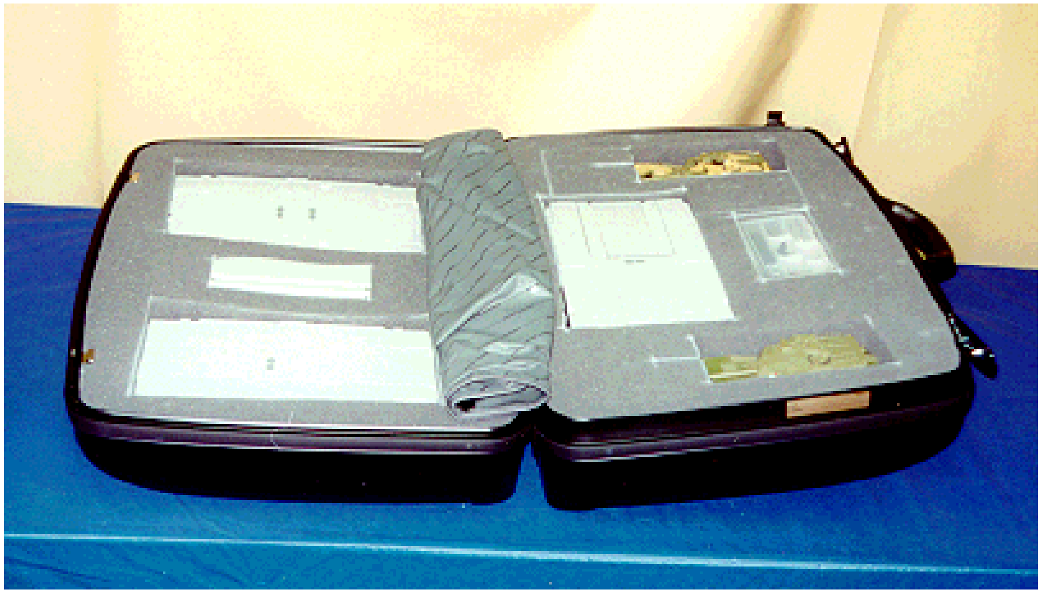
At a forward logistics site, the 24-ft wide ACBL Tri-Modules are deployed from the transport ship and assembled into lighters, causeways, and platforms such as the Roll-On/Roll-Off Discharge Facility platform and Air Cushioned Vehicle Landing Platform.



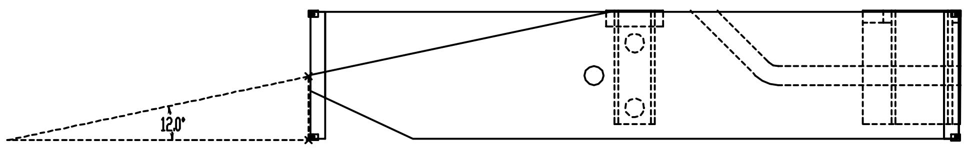
An M1 tank crossing beach ramp



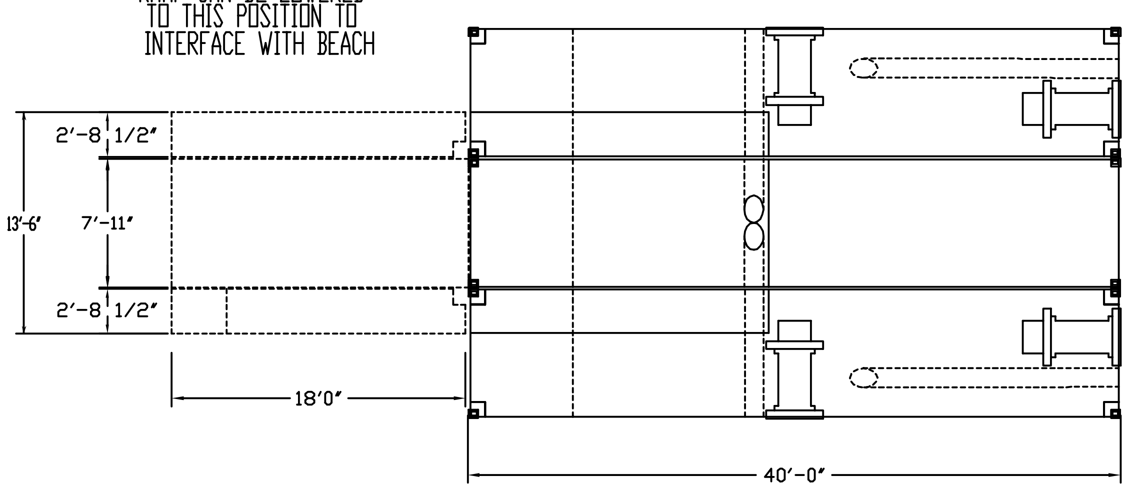
Assembled causeway section "underway" with cargo.



The transport “ship” for these 1/35th-scale ACBL
Tri-Modules happens to be a suitcase!



RAMP CAN BE LOWERED
TO THIS POSITION TO
INTERFACE WITH BEACH



NOTES:

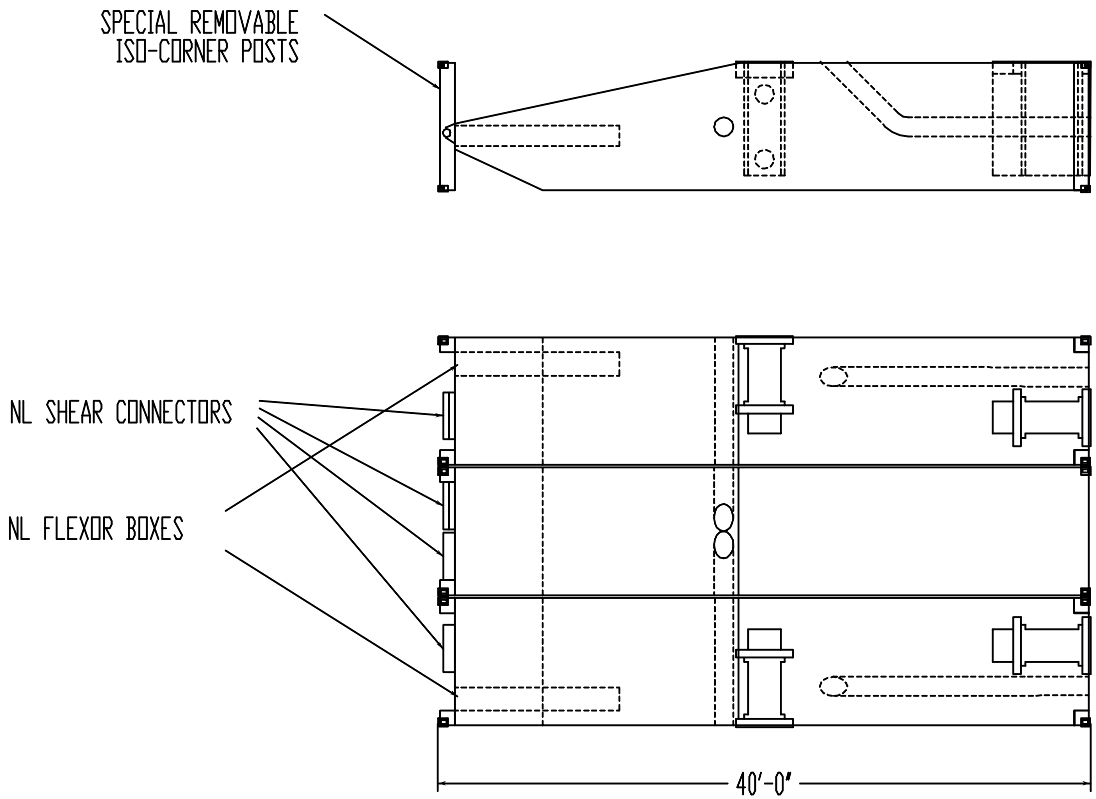
1. INDIVIDUAL TRI-MODULES ARE TRANSPORTED WITH RAMP SECTIONS HINGED CLOSED.
2. ISO-CORNER POSTS ARE REMOVED FROM OUTER MODULES AND OUTER MODULES ARE JOINED TO CENTER MODULE TO FORM 24-FOOT WIDE TRI-MODULE AS FOR OTHER TRI-MODULES.
3. OUTER 2-FOOT 8 1/2-INCH RAMP SECTIONS ARE CONNECTED TO CENTER 7-FOOT 11-INCH RAMP SECTION TO FORM OVERALL 13-FOOT 6-INCH WIDE RAMP.
4. RAMP ACTUATION MECHANISMS IN EACH OUTER MODULE ARE CONNECTED TO RAMP.
5. RAMP MAY THEN BE OPERATED BY EITHER OR BOTH RAMP ACTUATION MECHANISMS.
6. OTHER FEATURES ARE SIMILAR TO RAKE-END TRI-MODULE.
7. FOR STACKING ON T-ACS OR OTHER CONTAINER SHIP, SHORT EXTENDER LEGS MUST BE FITTED TO CENTER MODULE ISO-CORNERS AT RAMP END.

Prepared for
Naval Facilities Engineering Service Center, (NFESC) Port
Hueneme, California

UNLESS OTHERWISE SPECIFIED DIM/TOLERANCES ARE IN IN. ONE PLACE (X) ± ; TWO PLACE (XX) ± ; THREE PLACE (XXX) ± ; ANGLES ± ; THIRD ANGLE PROJECTION	DRAWN BY R. B. PAGE — DATE 4/30/96; CHECKED BY M. J. PLACKETT — 4/30/96	M. J. PLACKETT & ASSOCIATES, 9515 WOODWORTH AVENUE, GIG HARBOR, WA 98332; 30487 PETERSON ROAD, CORVALLIS, OR 97333
DO NOT SCALE THIS DRAWING; FOR INTERPRETATION OF DRAWING DOD-STD-100 APPLIES	CONTRACT NO. N47408-95-C-0201	TRI-MODULE ACBL BEACH-END RAMP
REMOVE BURRS AND BREAK SHARP EDGES; SHARP EDGES TO; FILLET RADII TO	DESIGN APPROVAL; DATE	
CAD DATA BASE FILE NAME:	APPROVED FOR PROCUREMENT; DATE	SIZE D; CAGE CODE 0W6P1; DWG NO. MJP&A/ACB/018; SCALE 1/48 FULL-SIZE; SHEET 1 OF 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



NOTES:

1. TOP DECK IS SLOPED IN A SIMILAR MANNER TO BEACH-END TRI-MODULE WITH RAMP REMOVED.
2. OUTER TRI-MODULES EACH INCORPORATE ONE NL FLEXOR HOUSING AND ONE SECTION OF SHEAR CONNECTOR AS FOR MCS WITHIN AN OVERALL LENGTH OF 40 FEET.
3. CENTER MODULE INCORPORATES OTHER SHEAR CONNECTORS AS FOR MCS WITHIN AN OVERALL LENGTH OF 40 FEET.
4. INDIVIDUAL TRI-MODULES ARE TRANSPORTED WITH SPECIAL ISO-CORNER POSTS FITTED.
5. ISO-CORNER POSTS ARE REMOVED FROM OUTER MODULES AND OUTER MODULES ARE JOINED TO CENTER MODULE TO FORM 24-FOOT WIDE TRI-MODULE AS FOR OTHER TRI-MODULES.
6. FOR STACKING ON T-ACS OR OTHER CONTAINER SHIP, SPECIAL EXTENDER LEGS MUST BE FITTED TO BOTH TOP AND BOTTOM OF CENTER MODULE TO MEET ISO-CORNER REQUIREMENTS.
7. FUTURE DEVELOPMENT MIGHT INCLUDE VERTICAL ARTICULATION OF TRI-MODULES TO ALLOW CONNECTION TO NL/MCS AT WIDE RANGE OF LOADING CONDITIONS.

Prepared for
Naval Facilities Engineering Service Center, (NFESC)
Port Hueneme, California

UNLESS OTHERWISE SPECIFIED DIM/TOLERANCES ARE IN. ONE PLACE (X) ±; TWO PLACE (XX) ±; THREE PLACE (XXX) ±; ANGLES ±. THIRD ANGLE PROJECTION	DRAWN BY R. B. PAGE — DATE 4/30/96; CHECKED BY M. J. PLACKETT — 4/30/96	M. J. PLACKETT & ASSOCIATES, 9515 WOODWORTH AVENUE, GIG HARBOR, WA 98332; 30487 PETERSON ROAD, CORVALLIS, OR 97333
DO NOT SCALE THIS DRAWING; FOR INTERPRETATION OF DRAWING DOD-STD-100 APPLIES	CONTRACT NO. N47408-95-C-0201	TRI-MODULE ACBL NL/MCS INTERFACE RAMP
REMOVE BURRS AND BREAK SHARP EDGES; SHARP EDGES TO; FILLET RADII TO	DESIGN APPROVAL; DATE	
CAD DATA BASE FILE NAME:	APPROVED FOR PROCUREMENT; DATE	SIZE D; CAGE CODE 0W6P1; DWG NO. MJP&A/ACB/019; SCALE 1/48 FULL-SIZE; SHEET 1 OF 1